TEMPORAL AND SPATIAL DISTRIBUTION AND ABUNDANCE OF JUVENILE HUMPBACK CHUB AND ADULT RAINBOW TROUT IN THE COLORADO RIVER IN GRAND CANYON, 1998-2000

DRAFT FINAL REPORT

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EXECUTIVE SUMMARY

Abundance and distribution of juvenile humpback chub (*Gila cypha*) and adult rainbow trout (*Onchorhyncus mykiss*) were monitored over a two-year period in the mainstem Colorado River (MCR) in a 8.4 mile reach below the confluence of the Little Colorado River (LCR). This LCR Inflow reach was sampled three times annually (June, September, January) between June 1998 and January 2000. In addition, sampling was conducted during spring, summer and fall in the LCR (March 1998-November 1999) near the confluence and 10.5-11.5 km upstream to monitor abundance and reproductive success of the resident humpback chub (HBC) population.

To maintain continuity with past MCR studies funded by the Glen Canyon Environmental Studies (GCES) program, a boat-mounted electroshocker was used to sample fish along shorelines. In the LCR Inflow, electrofishing comprised 108 samples taken along 59 shoreline areas from rm 60.1 to rm 68.5 and totaled 19.33 hr of effort. Compatibility with past GCES habitat studies and ongoing sampling in the LCR was addressed by use of hoopnet and minnow trap sampling methodology in the LCR Inflow of the MCR. Three 600-m hoopnet-minnow trap sampling subreaches were established in the LCR Inflow and were chosen to represent the range of geomorphic shoreline and river channel habitats in upper Grand Canyon. In the three subreaches, 507 hoopnet-minnow trap paired sets were made at established sampling locations spaced at 20 m intervals and total effort exceeded 21,000 hrs of set time. More than 90

days of sampling with hoopnets and minnow traps were conducted in the LCR during spring, summer, and fall periods.

A total of 637 individuals and 12 species were captured in hoopnets and minnow traps set in the Inflow reach. Juvenile HBC (n=272) and adult RBT (n=250) were co-dominant species in the catch and showed seasonal peaks in abundance during September sampling periods, but abundance of juvenile HBC declined to very low levels by January. Juvenile HBC <100 mm TL (YOY) and larger juveniles (100-200 mm TL) showed different patterns of abundance; larger juveniles were more abundant in September samples, but increased abundance of YOY was consistently tied to flooding in the LCR, the source of small, dispersing HBC. Abundances of juvenile HBC and adult RBT were complementary among the three sample subreaches; each species showed the greatest abundance where the other species was least abundant.

A total of 950 individuals and 8 species were captured in electrofish sampling conducted in the LCR Confluence and Inflow reaches of the MCR. Unlike hoopnet-minnow trap sampling, adult RBT was the dominant species (n=608) while juvenile HBC was a distant second (n=151). As with the hoopnet-minnow trap sampling, juvenile HBC showed seasonal peak abundance during September sampling and declined to very low levels by January. Unlike hoopnet-minnow trap samples, seasonal abundance of RBT among electrofishing subreaches did not parallel that of juvenile HBC, but remained relatively constant or increased over time. In addition, larger juvenile HBC were much less abundant than YOY, and did not show large increases in abundance during September sampling as did YOY.

Inspection of length-frequency distributions of HBC from the Inflow reach of the MCR and from the LCR allowed tracking of cohorts of juvenile HBC. For all sampling periods, size distributions of juvenile HBC captured in the MCR matched size distributions of HBC in the

LCR, which reinforced past studies that concluded that the LCR was the source of juvenile HBC captured in the MCR. However, the close match during winter and spring sampling suggested that low levels of dispersal of juvenile HBC occur year-round. Moreover, the analysis indicates that there is no measurable recruitment of juvenile HBC in the MCR and their presence is maintained by ongoing dispersal from the LCR, although levels fluctuate seasonally.

The patterns of seasonal abundance of juvenile HBC and their dispersal from the LCR and a lack of evidence of recruitment indicate that the MCR does not provide suitable habitat for juvenile HBC in Grand Canyon. The large population of resident adult RBT in the MCR and their increased catchability in hoopnets during peaks in abundance of juvenile HBC and subsequent declines in abundance of juvenile HBC suggests a strong predator-prey interaction. Vulnerability of juvenile HBC to predation is enhanced by poor habitat conditions, chronic cold temperatures, and frequent displacement caused by fluctuating flows.

Results of our study emphasize the dependency of HBC persistence in Grand Canyon on the LCR, where reproduction and successful recruitment has been demonstrated repeatedly in studies conducted over the past 20 years. Changes in operation of Glen Canyon Dam that would improve environmental conditions in the LCR Inflow reach of the MCR to enhance survivorship of juvenile HBC should consider stabilization of daily flow fluctuations and warmer epilimnetic releases. Implementation of these changes are complicated by the presence of non-indigenous species that would likely increase in abundance and possibly counteract improved conditions for juvenile HBC. However, an adaptive management program should be able to address the complexity of restoration of more natural ecosystem function in the MCR and determine strategies for implementing actions that over time will lead to improved status of HBC in Grand Canyon.

INTRODUCTION

From late 1990 through 1994, the Glen Canyon Environmental Studies (GCES) Phase II Program implemented a program of intensive sampling of fishes of the mainstem Colorado River (MCR) in Grand Canyon. The focus of this sampling was to assess the status of the endangered humpback chub (*Gila cypha*) in the Colorado River in Grand Canyon. Earlier investigations and the GCES studies showed that successful reproduction and recruitment of humpback chub (HBC) could only be demonstrated in the Little Colorado River (LCR), the location of the largest reproducing population of HBC (Kaeding and Zimmerman 1983, Gorman 1994, Valdez and Ryel 1995, Douglas and Marsh 1996, Robinson et al. 1998, Gorman and Stone 1999). Small, young-of-year (YOY) and juvenile (<200 mm TL) HBC appeared to disperse from the LCR to the MCR during late summer following monsoon flooding in the LCR (Valdez and Ryel 1995, Robinson et al. 1998). This pulse of small fish was most abundant in the reach of the Colorado River immediately downstream of the LCR confluence and was referred to as the LCR Inflow (Valdez and Ryel 1995). In the summer and fall, the abundance of smaller HBC peaked and then rapidly declined during fall and winter months and YOY essentially disappeared by the following spring (Valdez and Ryel 1995). Estimate of survivorship of YOY HBC for three years in the MCR was less than 0.001 (Valdez and Ryel 1995).

The fate of YOY and juvenile HBC in the Colorado River in Grand Canyon is of interest for several reasons. First, future dam operations may call for releases to create spring spike floods as was tested in 1996. These floods are thought to be useful in rejuvenating backwater habitats and flushing exotic fishes from the system (Hoffnagle et al. 1999), both of which may be beneficial to native fishes. Unfortunately, these artificial floods may also flush YOY HBC from the LCR Inflow, resulting in loss or mortality. Such actions are considered incidental "take" under the Endangered Species Act and every effort is taken to reduce the loss of these fish. If the abundance of YOY HBC has already been greatly reduced by spring, incidental take by implementing spring spike flows would be minimal. Other reasons for interest in the loss of YOY and juvenile HBC from the inflow are related to recovery strategies for the species. Current dam operations (i.e., daily fluctuating cold flows) may be contributing to the observed loss, in combination with strong predation by a large MCR population of rainbow trout (RBT). It might be possible to create an environment more favorable to recruitment of YOY HBC in the Colorado River in Grand Canyon by changes in dam operations, such as steady flows and elevation of flow release temperatures.

In this report, we characterize seasonal patterns of abundance and distribution of YOY and juvenile HBC (<200mm) and adult RBT in the LCR Inflow reach of the Mainstem Colorado River in Grand Canyon over the period 1998-2000. Past assessments of small HBC relied almost entirely on a boat-mounted electroshocker (e.g., Valdez and Ryel 1995). In order to maintain continuity with past sampling, we employed electrofish sampling in the MCR and closely followed established sampling methodologies. To gain additional resolution of habitat associations, intra- and inter-specific interactions in the MCR, and provide comparable data with past and present sampling in the LCR, we employed hoopnet and minnow trap sampling. To provide further compatibility with LCR hoopnet-minnow trap sampling, we used the same methodologies in both streams, including the design of nets, spacing of nets, sampling protocols, size of study reaches, and measurement of habitat. This tandem sampling design allowed us to evaluate seasonal patterns in the distribution and abundance of juvenile HBC in the MCR in the context of reproductive success in the LCR and seasonal flooding that lead to downstream transport of small fish.

METHODS

In our study, we follow Valdez and Ryel's (1995) definition of "juvenile" HBC (JHBC) as fish <200 mm TL. This broad category contains YOY and fish aged 3 or more years (Kaeding and Zimmerman 1983). In the LCR, year classes or cohorts of JHBC are easily discriminated (e.g. Gorman 1994). To provide more resolution in tracking HBC cohorts in the MCR, we defined YOY as fish <100 mm TL for some analyses, with the understanding that this group is a mixture of YOY and yearlings (as shown in Gorman 1994). In those analyses where HBC <100 mm TL were identified as smaller juveniles or "YOY," the complement subgroup of larger juveniles ≥100 mm TL was also identified. In our analysis of MCR and LCR HBC cohorts, we identified distinct YOY cohorts by size on length-frequency histograms to distinguish them from larger, older juveniles.

Sampling locations and fishing methods

To address patterns of abundance of YOY and juvenile HBC in the MCR, we examined data collected in the MCR and LCR during 1998-2000. Data from six sampling trips on the MCR and five sampling trips on the LCR were considered (Table 1). Though we sampled sites throughout the 225-mile MCR reach from Lee's Ferry to Diamond Creek, in this report we considered only data collected between river miles (rm) 60.1 – 68.6. This MCR reach is located from just above the LCR Confluence to just above Tanner Rapid. For most analyses we focused on the MCR reach immediately below the LCR Confluence to Tanner Rapid, and is referred to as the "LCR Inflow" reach. The Salt Camp sampling reach within the LCR proper extends from approximately 10.5 to 11.6 km upstream from the confluence with the MCR. Sampling in the lower-most LCR just above the MCR-LCR Confluence includes the lower 2 km of the LCR proper.

Mainstem Colorado River sampling locations and fishing methods

Three gear types were used to sample fish and characterize trends and abundance of the dominant species of the LCR Inflow: (1) electrofishing, (2) hoopnets, and (3) minnow traps. Besides YOY and juvenile HBC, we analyzed trends and abundance of rainbow trout (RBT, *Onchorhyncus mykiss*), fathead minnow (FHM, *Pimephales promelas*), and speckled dace (SPD, *Rhynichthyes osculus*).

Electrofishing followed methodology by Valdez and Ryel (1995) and sampling areas were delineated by geomorphic shoreline types, e.g., vegetated bank, debris fan, bedrock, etc. Our intent was to follow Valdez and Ryel's methodology and sample areas of the LCR Inflow in the same manner in order to maintain continuity of data collection with previous studies. Toward this end, we used the same electrofishing boat, equipment and boat operator as was used during Valdez's and subsequent studies from 1990-1996. Among sampling trips, we spent 2.8-3.7 hours of effort within the LCR Inflow (Table 2). Usually, electrofishing was conducted during darkness within 4 hours following sunset, or in some cases during the day when floodwaters from the LCR caused high turbidity in the MCR. Sample sites were relatively small and were subjectively chosen as representative of a distinct geomorphic shoreline type and varied widely in size and duration of the sampling effort (200s to >1500 s of electrofishing). In an evening, a series of semi-contiguous sites were sampled which represented a distinct MCR subreach (or part thereof). Partitioning of sampling area into contiguous sampling sites allowed pooling of data from individual sites for each subreach and sampling period. Alternately, pooling of data from individual sites by habitat type within a MCR subreach would permit analysis of habitat association by individual species (to be presented in a separate report). During successive nights, different subreaches were sampled so that over the course of a sampling period (5-6 days), a large portion of the LCR Inflow was sampled. Although there was considerable overlap in sample areas between sampling trips, there were no standard sampling areas or standard durations of sampling. Thus, there was wide variation in the size and duration of individual site samples and in pooled samples as well.

Hoopnet and minnow trap sampling was conducted following methodologies developed in GCES-funded studies in the LCR and outlined in Gorman (1994), Gorman and Stone (1999), and Stone (1999). Hoopnets were approximately 1 m long (not including the cod end) by 0.5 m diameter and constructed with 6 mm mesh netting. Standard Gee's minnow traps were approximately 0.5 m long by 0.25 m diameter and constructed with 6 mm mesh hardware cloth. In previous GCES studies in the LCR, hoopnets were set along cross-channel transects at evenly-spaced intervals (4-5 m) and minnow traps were set at the margins of transects to sample near-edge habitats <50 cm deep (Gorman 1994, Stone 1999). Cross-channel transects were spaced at 20-m intervals, creating a large systematic sampling grid of hoopnets. Because sampling along cross-channel transects was not feasible in the MCR, we modified the sampling design by setting a single hoopnet and minnow trap near the stream edge at locations spaced at 20-m intervals. Hoopnets and minnow traps were set as close as possible to the stream margin where depth was adequate; 15-50 cm for minnow traps and >50 cm for hoopnets. This new protocol was adopted for both MCR and LCR sampling in 1998-1999 to maintain continuity of the parallel studies.

Hoopnets and minnow traps were fished in pairs along standardized transects established within three ~600 m subreaches in the LCR Inflow: Hopi-Salt (rm ~63.3-63.8), Lava Chuar (rm

~65.2-65.5), and Tanner (rm ~68.0-68.5). Transects were spaced at 20m intervals and locations marked with an aluminum tag to allow precise re-occupation between sampling periods. Habitat was measured along transects perpendicular to the shoreline and in grids around hoopnets and minnow traps to determine habitat associations for MCR fishes (results described in a separate report). Hoopnets and traps were set in pairs (30 pairs per subreach), with hoopnets set to sample areas >50 cm depth and minnow traps usually set to sample depths <50 cm. The use of a hoopnet complemented by a minnow trap as a sampling unit was effective in capturing fish over a range of depths from 15 cm to more than 100 cm and from stream edge to more than 1.5 m out. Nets and traps were run (emptied of fish) twice at ~24 h intervals and were pulled after 40-48 hrs. Unlike electrofishing, hoopnet/minnow trap sampling effort was highly standardized because standard nets and traps had identical effort (time set) within a subreach. Total effort among the three subreaches was relatively consistent between sampling periods, varying between 3,769 and 3,995 hours. The June 1998 trip was exceptional because hoopnet/minnow trap operations were not initiated in the Tanner subreach until the fall 1998 trip.

Other methods employed in sampling fish in the MCR included trammel nets and seining. Relatively few juvenile HBC were captured by these methods and data from these sampling efforts were used only in developing length-frequency histograms for cohort analysis.

In the context of the analyses that follow, data collected using electrofishing and hoopnet/minnow trap gear were used to calculate catch-per-unit-effort (CPUE) as a measure of the relative abundance of YOY and juvenile HBC. Additionally, the lengths of fish captured by all methods were used to characterize the length-frequency composition of HBC within the LCR Inflow reach.

Data collected for each sampling effort included: (1) gear type, (2) location, (3) effort, (4) number of each fish species captured, (5) total length and weight of each captured fish, (6) sex and ripeness (if possible to determine), (7) tag number (if fish was tagged), and (8) a suite of habitat characteristics. Fish total length was measured to the nearest millimeter and weight was measured to the nearest 0.1 gram for fish smaller than approximately 200 g, and to the nearest gram for fish larger than 200 g. Total length was measured using a standard measuring board and weight was measured using a portable electronic balance.

Little Colorado River sampling locations and fishing methods

Data collected within the Salt Camp and LCR Confluence reaches of the LCR were used to characterize the length composition of HBC in the LCR. Fish were captured using hoopnets and minnow traps set along shorelines at established sampling locations. Seines were used to sample fish in discrete areas near shorelines. Data collection generally proceeded as described above. Sampling in the Salt Camp reach was conducted with pairs of hoopnets and minnow traps at established sampling locations spaced at 20m intervals from km 10.5-11.5. Nets and traps were set for 24 hrs, run, and moved to new locations moving in an upstream direction. Habitat was characterized by measurement of habitat variables along transects at sampling locations and in grids around nets and traps. For a more thorough description of Salt Camp sampling protocol, see the Grand Canyon Environmental Studies final report (Gorman 1994). Most LCR Confluence sampling was done in the lower 2 km at established sampling locations used in long-term monitoring of native fishes (Hoffnagle 2000).

Catch Per Unit Effort (CPUE)

Geometric mean CPUE was calculated for the results of hoopnet/minnow trap sampling for the entire LCR Inflow reach and for hoopnet/minnow trap efforts within each subreach. Geometric mean CPUE for each reach was estimated as

$$GM_{CPUE} = \exp\left[\frac{\sum \log_e\left(\frac{f}{e}+1\right)}{n}\right]-1, \tag{1}$$

where GM_{CPUE} is the geometric mean CPUE, f is the number of fish captured for each sample (hoopnet/minnow trap pair), e is the effort (hours set) for each sample, and n is the number of samples collected in each standardized reach. CPUE for hoopnet/minnow trap sampling was expressed as number of fish per 100 hr of set time.

Usually, the use of the geometric mean to estimate central tendency of CPUE data is justified because of a large number of sampling efforts with zero catch for a particular species or because of high variability in number of fish caught among samples (Sokal and Rohlf 1987, Valdez and Ryel 1995). Log-transformation is intended normalize CPUE data, which are notorious for their lack of normal distributions (Hubert 1996).

Typically, >50% of all nets/trap pairs in each of our sample areas yielded zero catch for HBC juveniles, our species of interest. Distributions of low-catch species usually conform to a negative binomial (Elliot 1977) and log transformation is recommended to normalize the data. However, catch-frequency distributions from low-density populations may not be successfully normalized by transformation (Hubert 1996). In our case, log transformation linearized our HBC hoopnet/minnow trap catch data and compressed the data range closer to zero, thereby reducing bias caused by values in the tail of the distribution and from the preponderance of zeros. Thus, our use of the geometric mean may provide a more useful index of CPUE than does arithmetic mean. Hubert (1996) proposed that the median might be a useful statistic for CPUE because assumptions of normality are rarely achieved. However, the median is not a useful statistic for our low-density populations because that value is invariably zero for juvenile HBC.

Electrofish sampling was not conducted in a standardized manner, i.e., neither effort (time or distance or area sampled) nor location of sample sites were standardized (neither systematic nor stratified nor random) for any of the subreaches. Therefore, usual statistical approaches were not valid for these data. The results of electrofishing data were pooled for the following Colorado River LCR Inflow subreaches: Above Little Colorado River Confluence (ABLC) (rm 60.0-61.5), Crash (rm 61.6-62.8), Hopi-Salt (rm 62.9-64.0), Carbon-Lava Chuar (rm 64.1-65.5), and Tanner (rm 66.8-68.6). Note these subreaches from ABLC to Carbon-Lava Chuar are largely contiguous. Pooling of individual subsamples for each subreach and sampling period was justified because location and effort varied widely among subsamples. Without pooling, calculation of mean CPUE from our subsamples incorrectly dispenses effort from zero catches and produces distorted rates of catch. Thus, we calculated CPUEs for each species from pooled data for each subreach and sample period. Following preliminary review, further pooling of subreach data was necessary to achieve a minimum of 2000 sec (0.56 hr) per sampling period per subreach. This level of pooling yielded minimum CPUE rates of 1.0 fish/hr, and avoided interjecting unreliable data into CPUE calculations. We also analyzed the relationship between sample size and variance of total catch and found that the range of variance stabilized for samples >1000 sec for all fish combined, and >2000 sec for HBC. We applied this finding by pooling data from ABLC and Crash (rm 60.0-62.8, 2.8 mile subreach) to create the "ABLC-Crash" electrofishing subreach. Data from Hopi-Salt and Carbon-Lava Chuar were merged (rm 62.9-65.5, 2.6 mile subreach) to create the "HS-Carbon" subreach. Tanner remained separate as before (rm 66.8-68.5, 1.7 mile subreach), but as noted previously, was not sampled in June 1998. The HS-Carbon electrofishing subreach includes the Hopi-Salt hoopnet/minnow trap sampling subreach (rm 63.3-63.8) and Lava Chuar hoopnet sampling subreach (rm 65.2-65.4). The Tanner electrofishing subreach includes the Tanner hoopnet/minnow trap sampling subreach (rm 68.0-68.5).

Association of HBC and RBT

Association of juvenile HBC and RBT in hoopnet/minnow trap subreaches were evaluated by application of a binomial probability [$(p+q)^2$] to generate expected frequencies of occurrence of one or the other or both species at hoopnet/minnow trap sample locations within the LCR inflow. Using hoopnet and minnow trap data, significant differences in observed and expected frequencies were evaluated with a X^2 test. Differences in proportions of HBC and RBT caught together or separately among the hoopnet sampling subreachs were further analyzed with a contingency table analysis.

Length-frequency plots

HBC length-frequency distributions were plotted for each sampling trip in the MCR and for corresponding trips in the LCR. Inspection of these plots allowed us to determine the contribution of YOY and juvenile HBC to the composite sample of HBC collected during sampling trips in the MCR, and to infer what sizes of fish were possibly emigrating from the LCR during corresponding time periods.

RESULTS

Sampling overview

Over the period of study, 6 monitoring trips were conducted in the mainstem Colorado River in Grand Canyon (June 1998-January 2000), and 6 trips were conducted in LCR (March 1998-November 1999) (Table 1). In the mainstem LCR Inflow reach, electrofishing comprised 108 samples taken along 59 shoreline areas from rm 60.1 to rm 68.5 and totaled 19.33 hr of effort. In the Hopi-Salt, Lava-Chuar, and Tanner subreaches of the LCR Inflow, 507 hoopnet-minnow trap sets were made at established sampling locations. Total hoopnet-minnow trap sampling effort exceeded 21,000 hr (Table 2). More than 30 days of sampling with hoopnets was conducted during each of the springs of 1998 and 1999 in the lower 3 km of the LCR (Boulders Camp to confluence). Additional sampling 10.5-11.6 upstream at the Salt Camp reach was conducted in the summer and fall of 1998 and 1999, and in the spring of 1999. Catch data from the LCR was used to generate seasonal size-frequency distributions of HBC to be compared with HBC data from the mainstem LCR Inflow reach.

Total catch, community composition and population size structure.

A total of 637 individuals and 12 species were captured in hoopnets and minnow traps set at established locations in the LCR Inflow from June 1998 to January 2000 (Table 3). Overall, HBC and RBT were co-dominant species in the catch, but they were not evenly distributed among the reaches. HBC were more dominant in the Hopi-Salt subreach and least dominate in the Tanner subreach. RBT followed the opposite pattern. Size composition of the two species differed markedly (Figure 1); nearly all HBC (98%) were juvenile fish <200 mm TL (only 6 of 278 HBC were >200mm TL) while most RBT (90%) were >200 mm TL (only 27 of 277 RBT captured were <200 mm TL) and all larger RBT were captured exclusively in hoopnets. The next most common species were SPD and FHM, although their relative abundance was much lower than HBC or RBT.

A total of 950 individuals and 8 species were captured in the electrofish sampling conducted in the LCR Confluence and Inflow subreaches (Table 4). Unlike the hoopnet sampling, RBT was the dominant species (n=659) while HBC (n=154) was a distant second. As with the hoopnet/minnow trap sampling, adult RBT predominated (608 of 659 or 92% were >200mm TL) while juvenile HBC predominated (151 of 154, or 98%, were <200 mm TL) (Figure 2). However, the proportion of smaller YOY HBC in electrofish sampling (92 of 154 or 60%) was greater than in hoopnet/minnow trap sampling (110 of 278 or 40%) (Figures 1, 2). Like the hoopnet/minnow trap sampling, SPD and FHM were the next most abundant species.

A breakdown of size composition of HBC showed strong differences between hoopnet and minnow trap samples (Figure 3). Larger juveniles (100-200 mm TL) predominated in hoopnet samples (72.3% of all HBC) while YOY predominated in minnow trap samples (72.2% of all HBC). Differences in size composition between the two gear types may be related to differences in gear selectivity and habitat sampled. Minnow traps were much smaller than the hoopnets (0.5 m vs. 1.0 m length) and had a smaller throat size (~3 cm vs. 10 cm) and minnow traps were set in shallower habitats (<50 cm) while hoopnets were set in deeper habitats (>50 cm). The size composition of HBC from minnow trap samples is very similar to that from electrofishing samples where YOY comprised 59.7% of all HBC (Figures 2, 3). Reduced abundance of larger juveniles in electrofishing samples caused differences in size composition of HBC observed in Figures 1 and 2.

Composition of HBC size cohorts varied among the Inflow subreaches. Among the hoopnet subreaches, Hopi-Salt had the highest proportions of medium (100-150 mm TL), and large (150-200 mm TL) juvenile HBC but the smallest proportion of small HBC ("YOY", <100 mm TL) (Figure 1). Compared to Hopi-Salt, Lava-Chuar had a larger proportion of small juveniles and a smaller proportion of large juveniles. In the farthest downstream subreach, Tanner, the HBC population was dominated by small individuals. Size composition for RBT populations differed little among the subreaches; juvenile RBT were relative rare while larger RBT >200 mm TL predominated.

Among the electrofishing subreaches, small HBC predominated, but were relatively more dominant in the Tanner subreach (Figure 2). In comparison to the hoopnet subreaches, medium- and especially large-sized juveniles were relatively less abundant. Like the hoopnet subreaches, large RBT predominated in the electrofishing subreaches and RBT <200 mm TL were relatively uncommon (Figure 2).

Spatial and temporal variation in CPUE

Estimates of hoopnet/minnow trap geometric mean CPUE for juvenile humpback chub ranged between 0.12 fish/100 hours and 1.63 fish/100 hours for the entire LCR Inflow reach with the highest CPUEs occurring during September 1998 and 1999 sampling trips and lowest CPUEs occurring during 1999 and 2000 January sampling trips (Table 5, Figure 4). A similar pattern of results were observed for electrofishing pooled CPUEs in the LCR Inflow reach and varied from a low of 2 fish/hr to 19 fish/hr (Table 6, Figure 4).

Summary CPUE data was further subdivided to compare patterns of abundance in larger juveniles (HBC $\geq$100 mm TL) and YOY (HBC <100 mm TL) in the LCR Inflow by sampling gear and sampling period (Figure 4). As noted previously, abundance of juvenile HBC was greatest during September sampling periods. However, the composition of larger juveniles and

YOY in hoopnet/minnow trap samples and electrofishing samples differed strongly. Larger juveniles predominated in September hoopnet/minnow trap samples and YOY predominated in June samples, although June abundances were lower compared to that in September samples. In 1998, CPUE of YOY in hoopnet/minnow trap samples peaked in September, but in 1999, CPUE of YOY peaked in June but at a reduced level and decreased only slightly in September. In electrofishing samples, YOY predominated in September 1998 and 1999 (Figure 4). Larger juveniles showed a slight edge over YOY in June 1999 and January 2000 samples, but abundances were relatively low. CPUE of YOY and larger juveniles from electrofishing samples peaked in September of both years but in contrast to YOY, the relative abundance of larger juveniles had much less variation between sampling periods. As a result, most of the variation in abundance of juvenile HBC in electrofishing samples was caused by large seasonal variation in the abundance of YOY HBC (Figure 4). To summarize, most of the seasonal variation in abundance of juvenile HBC in hoopnet/minnow trap samples is caused by changes in abundance of larger juveniles while in electrofishing samples it is caused by changes in abundance of YOY.

In order to explore site and downstream distance effects on CPUE of juvenile HBC below the LCR confluence, we calculated hoopnet/minnow trap CPUEs separately for three subreaches within the LCR Inflow reach. During September of 1998 and 1999, CPUE of juvenile HBC was much higher at the Hopi-Salt and Lava Chuar subreaches compared with Tanner (Table 5, Figure 5). During June and January sampling periods, CPUE of juvenile HBC at the Hopi-Salt and Lava-Chuar subreaches was greatly reduced. Similar seasonal patterns of increased CPUE in September and decreased CPUE in June and January were observed in the electrofishing subreaches (Table 6, Figure 6).

The composition of larger juveniles and YOY HBC in hoopnet/minnow trap catch data among the subreaches was examined across seasons to reveal additional patterns (Figure 5). Hopi Salt and Lava Chuar subreaches were relatively similar in seasonal composition of larger and small juveniles. However, abundances of larger and smaller juvenile HBC in the Lava Chuar subreach peaked in September 1998 in contrast to September 1999 for the Hopi Salt subreach (Figure 4). Relative abundance of larger juveniles was greatly reduced in the Tanner subreach and the abundance of YOY in 1999 peaked in June in contrast to the September 1998 peak. Differences in patterns of size composition of juvenile HBC among the electrofishing subreaches showed less variation compared to hoopnet/minnow trap samples (Figure 6). The HS-Carbon and Tanner subreaches showed similar seasonal changes in size composition of juvenile HBC with the exception of the disappearance of juvenile HBC in the January 2000 Tanner subreach.

Seasonal and downstream patterns in hoopnet-minnow trap CPUEs among the LCR Inflow subreaches are summarized in Figures 7-9. Overall, the relative abundance of YOY was similar among the subreaches but larger juveniles were relatively abundant only in the Hopi Salt and Lava Chuar subreaches (Figure 6). Overall mean CPUEs of juvenile and YOY HBC peaked during the September sampling period and was comprised mostly of larger juveniles (Figures 8, 9). The lowest mean CPUEs for juvenile and YOY HBC occurred during January sampling periods, though CPUEs for June sampling periods were marginally higher. Smaller juveniles predominated in June samples (Figures 8-9).

Seasonal and spatial patterns of community composition

As mentioned previously, the two most common species captured in hoopnets and minnow traps in the LCR Inflow subreaches were HBC and RBT (Tables 3, 4). Other common but much less abundant species included fathead minnow (FHM) and speckled dace (SPD). Relative abundance of these species varied seasonally over the course of the study (Figure 10). Like HBC, CPUE of RBT from hoopnet-minnow trap samples peaked during September sampling periods. In contrast, RBT did not show a seasonal pattern of abundance in electrofishing samples (Figure 11). Abundance of SPD peaked in June hoopnet-minnow trap samples but peaked in September electrofishing samples. Abundance of FHM was higher in June and September 1998 compared to subsequent sampling periods for both hoopnet-minnow trap and electrofishing samples.

Among the hoopnet-minnow trap subreaches, RBT showed varying patterns of seasonal abundance (Figure 10). CPUE of RBT was consistently low at Hopi-Salt but showed increased abundance in the September samples in the Lava-Chuar and Tanner subreaches. Abundance of RBT was relatively high in both September samples from the Tanner subreach. Seasonal patterns in abundance were not clearly evident in the electrofishing samples (Figure 11); in the HS-Carbon subreach, RBT abundance was greater in January and June 1999 samples compared to other periods while in the Tanner subreach RBT show a trend of increasing abundance over time.

HBC and RBT interaction

During the September sample periods, the relative abundances of both HBC and RBT were relatively high in the hoopnet-minnow trap samples. To investigate possible association/disassociation between these predominant species, we compared the September distributions of HBC and RBT among the sample locations for hoopnets and minnow traps (data pooled for all subreaches) with that predicted by a binomial probability function (Table 7). For both September 1998 and 1999, the two species showed and significant segregation in the locations where they were captured (X^2, P<0.05), i.e., the two species were captured together at the same locations far less than expected. This segregation is shown graphically in Figure 12. When data were subdivided by subreach, the two species had distributions as predicted by the binomial probability function or they could not be statistically evaluated because of small sample sizes. The two exceptions were Tanner in September 1998 and Lava-Chuar in September 1999; in these examples, co-occurrence of RBT and HBC was less frequent that predicted by the model. A contingency table analysis showed that there were significant differences among sites in the distribution of HBC and RBT (Table 8). In particular, significant differences among the subreaches were caused by more HBC captured alone than expected in the Hopi-Salt reach for both years and more RBT was captured alone than expected in the Tanner reach for both years. This result was caused by the preponderance of HBC in the Hopi-Salt subreach and preponderance of RBT in the Tanner reach. Taken together, the two analyses showed that most of the segregation of the species was between sites and not among locations within sites. This between subreach segregation was suggested in the raw abundance data presented in Table 3 and CPUE presentations in Figures 13 and 14. Seasonal and between-site patterns of abundances of the two species are shown in Figure 14; JHBC was the predominant species in the Hopi-Salt subreach, the two species were roughly co-dominant in the Lava-Chuar subreach, and RBT was the dominant species in the Tanner subreach.

Linkage of seasonal and spatial patterns of abundance of juvenile HBC and adult RBT were not evident in data from the electrofishing subreaches (Figure 15). RBT did not follow the seasonal peaks in juvenile HBC abundance in the HS-Carbon subreach, instead, RBT abundance peaked in January and June 1999 and declined somewhat in September 1999 and January 2000. Juvenile HBC abundance declined over time in the Tanner subreach while RBT abundance increased.

Analysis of size cohorts for HBC

Length-frequency (L-F) distributions of HBC captured in the LCR Inflow allowed tracking of discrete size/age cohorts over time, especially YOY. Because the LCR was the source for small HBC in the MCR, L-F distributions for juvenile HBC from the LCR confluence (0-2 km) and the upstream LCR Salt Camp reach (~10-12 km) provided a frame of reference. For each area of consideration (Inflow reach, LCR Confluence, LCR-Salt Camp), L-F histograms of HBC were generated for each of the sampling periods from June 1998-January 2000 from catch data pooled from all sampling methods. The L-F distributions revealed detailed patterns of changing size/age structure for the HBC populations (Figures 16-21). Starting with June 1998, the L-F histograms showed that YOY (<50 mm TL in Figure 16) were present in the LCR but were not yet present in the Inflow Reach. The few juvenile HBC captured in the Inflow Reach in June 1998 were larger and most likely 1 and 2 year-old fish and roughly matched the size range of juveniles within the LCR. In September 1998, the more abundant juvenile HBC captured in the Inflow Reach were YOY and older/larger juveniles and closely matched the size distribution of juveniles found within the LCR (Figure 17). The size distribution of juveniles from the Inflow Reach and the LCR confluence were very similar in January 1999, and showed that the 1998 cohort increased from a modal size of 60 mm TL in June 1998 to 80-90 mm TL in January 1999 (Figure 18). In contrast to June 1998, YOY were present in the Inflow Reach in June 1999 (Figure 19). Once again, the size range of juveniles found in the Inflow Reach were similar to that found in the LCR. Like September 1998, the September 1999 Inflow Reach showed an increased relative abundance of juveniles compared to June and January (Figure 20). Unlike September 1998, larger juveniles were predominant in 1999 whereas smaller juveniles and YOY were predominant in 1998. As with September 1998, the size distribution of juveniles in the Inflow Reach in September 1999 was very similar to that found in the LCR during fall 1999. By January 2000, captures were greatly reduced, but the size range of juveniles captured in the Inflow Reach remained similar to that found in the LCR confluence (Figure 21). The modal size of YOY increased from 50-60 mm TL in September 1999 to 80 mm TL in January 2000. This pattern was very similar to the September 1998 and January 1999 comparison.

DISCUSSION

Seasonal abundance and recruitment of juvenile HBC in the Inflow Reach

Our observations of increased juvenile HBC abundance in the LCR Inflow reach of the MCR during late summer followed by decreasing abundance throughout the winter and spring was observed previously by Valdez and Ryel (1995). The increased abundance of these small fish in the LCR Inflow was correlated with summer flooding in the LCR that was triggered by seasonal monsoonal precipitation events. The smaller YOY HBC appear be vulnerable to flood-caused downstream transport (Robinson et al 1998). In 1998, spawning by HBC in the LCR was delayed by prolonged winter-early spring flooding until May (O. Gorman, pers. obs.) and monsoonal flooding in the LCR did not commence until late July. Thus, YOY HBC were not found in the LCR Inflow during June 1998 sampling but were relatively abundant in September.

In 1999, the usual winter and spring flooding did not occur in the LCR and HBC commenced spawning early during the winter months. Unusual recruitment of winter-spawned HBC timed with early monsoonal flooding in June lead to the presence of YOY HBC in the LCR Inflow during June 1999 sampling (particularly evident in hoopnet-minnow trap samples). In 1992, YOY HBC were also observed in the LCR Inflow during June and were tied to the early onset of monsoonal flooding in the LCR (Valdez and Ryel 1995).

The seasonal summer appearance of HBC YOY and larger juveniles and close concordance with L-F distributions of LCR fish suggested that there was little or no recruitment of small HBC in the Inflow reach of the MCR and the presence of these smaller HBC in the Inflow Reach was maintained by episodic summer dispersal from the LCR. This interpretation is supported by the studies of Valdez and Ryel (1995) and Robinson et al. (1998). While dispersal following summer monsoon flooding in the LCR was evident, continuing dispersal at low levels during winter and spring months was apparent only by close inspection of L-F distributions of catch from the LCR and the Inflow Reach. Small YOY in the Inflow Reach were the same size range as those present in the LCR and showed the same seasonal increase in size as the cohorts in the LCR. The mainstem CR is a cold, stenothermal environment and is maintained by hypolimnetic releases from Glen Canyon Dam. Growth experiments on HBC by Gorman and VanHoosen (2000) and Clarkson and Childs (2000) demonstrated that small HBC do not show appreciable growth at temperatures of 12°C or less and temperatures in the Inflow Reach almost never exceeded 11°C (based on our own temperature records). Thus, if small HBC persisted in the LCR Inflow, their growth would be arrested and the size composition of the population would show an accumulation of small fish and a lack of concordance with LCR L-F distributions. As this was not the case, loss of small HBC in the Inflow Reach must be relatively rapid-- essentially all small fish disappearing within 90 days from peak abundance in September to a January nadir. The presence of small HBC in the Inflow Reach appeared to be maintained by ongoing dispersal from the LCR rather than persistence.

While smaller YOY HBC may be vulnerable to downstream transport by flood events in the LCR (Robinson et al. 1998), larger juvenile HBC (100-200 mm TL) do not appear to be so vulnerable (Gorman 1994). Nonetheless, peak abundance of these larger juveniles occurred during September 1998 and 1999 hoopnet-minnow trap sampling and their precipitous declines during the following winter and spring sampling paralleled that of the smaller YOY HBC. The observation that YOY HBC dispersal peaked following monsoonal flooding in the LCR in late summer in 1998 and early summer in 1999 while dispersal of larger juveniles peaked in late summer of both years suggests different dispersal mechanisms for the two cohorts. The peak in abundance of small YOY HBC in the Inflow reach following seasonal flooding suggests that dispersal may be largely passive and is facilitated by flood flows. However, the increased abundance of larger juveniles only in late summer (and their low numbers or absence in other periods) and not strictly tied to seasonal flooding suggests active dispersal tied to biological factors. Differences in dispersal in the two size groups warrants further investigation, particularly since in 1998 and 1999 larger juveniles comprised the dominant component of small HBC in the Inflow Reach hoopnet-minnow trap samples (but only in late summer sampling periods).

Habitat differences among the Inflow subreaches

The Hopi-Salt subreach was characterized by large, talus-derived boulders, steep banks, and little shallow water. This area provided relatively complex habitat with much vertical structure and cover. The structural complexity of the Hopi-Salt subreach is similar to habitats in the LCR where juvenile and adult HBC show strong association (Gorman 1994). The Lava-Chuar subreach was comprised of a mix of vegetated and sand cut-banks and cobble-debris shorelines. Shallow areas were associated with cobble and moderate currents while deeper areas were associated with steep, cut-banks. This area offered less structural complexity compared to Hopi-Salt. The Tanner subreach was structurally similar to Lava Chuar.

Downstream dispersal and recruitment

YOY had similar levels of abundance across the three Inflow hoopnet-minnow trap subreaches (peaks of 0.3-0.6 fish/100hr sampling during summer months). Abundance of larger juveniles was much greater but only in September samples, ranging from 1.0-2.0 fish/100 hr sampling at the two upper subreaches (Hopi-Salt and Lava-Chuar) but remaining below 0.3 fish/100 hr for the downstream Tanner subreach. This suggests a decline in abundance of juvenile HBC moving downstream from the LCR Confluence, the point of entry of small HBC dispersing from the LCR into the Colorado River.

The observation of decreasing relative abundance of juvenile HBC over time or with increasing distance from the LCR Confluence in hoopnet-minnow trap samples is likely to be caused by a combination of dispersal and mortality. If dispersal were the dominant factor reducing CPUE as distance from the LCR is increased, we would expect to see some recruitment of juvenile HBC in other suitable habitat further downstream of the Inflow Reach. Recruitment of distinct cohorts has been observed in the LCR (Kaeding and Zimmerman 1983, Gorman 1994). In addition, larger juveniles and small adult HBC show a high level of site fidelity over considerable periods (>6 mos) (Gorman 1994; Gorman and Stone 1999), which increases the likelihood of recapture within discrete sampling reaches. In the MCR, only 63 of 565 juvenile HBC (11.2%) were captured downstream of the Inflow Reach (rm >69) during the 6 mainstem sampling trips conducted in 1998-2000. Additionally, only 14 (2.5%) of these fish were smaller than 100 mm TL. Of the 63 juvenile HBC captured downstream of the Inflow reach, 47 (74%) were captured during September sampling efforts, reflecting the same pattern of seasonal abundance as in the Inflow Reach. Only one of these fish was recaptured more than one day following tagging, a 191 mm TL juvenile marked in 9/99 in Middle Granite Gorge and recaptured in 1/00, all within a 1-km sampling reach. These observations suggest that throughout the Colorado River in Grand Canyon, there appears to be little or no recruitment of juvenile HBC and their presence is relatively ephemeral, i.e., juvenile HBC are relatively abundant in late summer months following flooding in the LCR and decline to low population levels in the following winter and spring.

Other species and seasonal and spatial patterns of abundance

HBC (especially juveniles) and RBT (especially large adults) were the dominant species of the Inflow Reach fish assemblage. Adult HBC and juvenile RBT were rare in our hoopnet/minnow trap and electrofishing samples. Other common species included two small minnow species, SPD and FHM, but they did not show strong seasonal peaks in abundance tied to monsoonal flooding in the LCR as did juvenile HBC. Possibly, a portion of the SPD and FHM MCR populations may be resident species in mainstem environments whereas juvenile HBC are ephemeral migrants dispersing from the LCR.

RBT was the dominant resident species of the mainstem fish assemblage and did not use the warm LCR environment. L-F histograms for RBT MCR populations suggest that RBT in the

MCR may be self-sustaining (Gorman & Van Haverbeke, data presented in separate report). The presence of cohorts of smaller fish and an abundance of larger reproductive adults (modal size=325 mm TL) support the interpretation of self-sustaining populations of RBT. Unlike SPD and FHM, the abundance of RBT in hoopnet-minnow trap samples followed the same strong seasonal pattern as juvenile HBC (peaked in late summer following LCR flooding events). Abundance of RBT varied among Inflow subreaches in a pattern that was complementary to the abundance of juvenile HBC. Size composition of RBT was also complementary to juvenile HBC—there was essentially no overlap in size—most HBC were <150mm TL while most RBT were >300 mm TL and they used the same near-shore habitats. Reasons for these patterns remain speculative but are consistent with expectations of a predator-prey interaction. RBT is a known predator of small fish in Grand Canyon (Marsh and Douglas 1998) and spot checks of RBT and BRT stomachs revealed remains of small fish, including HBC (pers. obs., Dennis Stone). Increased abundance of adult RBT in shallow areas inhabited by relatively abundant juvenile HBC may reflect a functional response by a large resident predator population. The similarity in size composition of HBC from electrofishing and minnow trap samples suggests that these two gears selectively capture smaller HBC in relatively shallow, nearshore habitats <50 cm depth. The relative abundance of adult RBT in electrofishing samples suggests that small HBC and RBT are using similar habitats.

At the Hopi-Salt subreach, the consistently low abundance of RBT may be related to the structural complexity of the habitat providing high levels of cover to small HBC, thus making them much less detectable or catchable by trout. The disappearance of small HBC at the Hopi-Salt subreach after summer suggests that this area does not offer suitable habitat for long-term survival or residency. The lower abundance of RBT in the Hopi-Salt hoopnet-minnow trap subreach contrasts with electrofishing data from this area of the MCR where RBT showed much higher catch rates than juvenile HBC and catch rates were relatively stable over time. This observation suggests that RBT was common in the Hopi-Salt subreach but were not in the same habitats used by juvenile HBC.

RBT-HBC predator-prey model

We propose the following predator-prey model for the RBT-juvenile HBC interaction in the Inflow Reach: RBT are large, resident, mainstem river piscivores that use habitats in response to prey abundance. HBC are adapted to the warm-water environment of the LCR, where successful reproduction and recruitment are possible. Many juvenile HBC disperse downstream into the cold MCR, especially during late summer when flooding in the LCR follows periods of monsoonal precipitation. Daily fluctuating flows in combination with cold water disrupt habitat associations of juvenile HBC and result in increased movement and loss of cover and increased vulnerability to predation. RBT are adapted to the cold temperatures of the MCR and their large size allows them to roam over large areas in search of prey despite the disruption of daily fluctuating flows. Increased catches of large RBT in near-shore habitats during periods of seasonal abundance of HBC suggests a functional, opportunistic response to increased prey abundance. It is likely that RBT consume nearly all small HBC that enter the Inflow Reach from the warm LCR within 90 days of their peak abundance in September to their nadir in January. Even if these juvenile HBC were able to avoid predation, they would not realize significant growth because of the cold-water conditions. Since HBC are only a seasonally abundant prey item, RBT must switch to other prey items and habitat use patterns at other times. Alternative prey would include macroinvertebrates and other small fishes (e.g., SPD and FHM), including their own species.

Electrofishing vs. hoopnets/minnow trap sampling

Results from electrofish sampling reflected some of the same patterns as hoopnet/minnow trap sampling, but also showed major differences. Results from both methods indicated a seasonal peak in abundance of juvenile HBC during summer months and dwindling numbers during winter and spring. In addition, both methods showed a preponderance of juvenile HBC and adult RBT in the Inflow reach fish assemblage. Both methods reflected similar seasonal patterns of abundance for the other small minnow species, SPD and FHM. However, differences in results from the two sampling methods were substantial. Hoopnet-minnow trap sampling captured more species (12 vs. 8), including bluehead sucker, yellow bullhead, channel catfish, and plains killifish. Hoopnet-minnow trap sampling showed that most juvenile HBC were >100mm TL, YOY and larger juveniles showed different patterns of seasonal abundance, and larger juveniles were largely responsible for seasonal differences in abundance of HBC in the LCR Inflow. Electrofish sampling showed that most juvenile HBC were (<100 mm TL), and these smaller fish were largely responsible for seasonal differences in abundance of HBC in the LCR Inflow. The electrofish sampling was not able to detect the early presence of YOY HBC in June 1999 sampling following early flood events in the LCR. Nor was electrofishing able to detect decreasing abundance of juvenile HBC, especially larger juveniles, in the Tanner subreach.

Size composition of HBC from electrofishing was similar to that from minnow traps and contrasted strongly with hoopnet samples. We suspect that differences in size composition are related to differences in sampling efficiencies of the two gears in different habitats. Minnow trap and electrofish sampling were conducted mostly in shallow, near-shore habitats (typically < 50 cm depth) while hoopnets were usually set in deeper water further from stream edge (> 50 cm depth and typically >1 m from edge). That difference likely explains the preponderance of YOY HBC in minnow trap and electrofish samples and the preponderance of larger juvenile HBC in hoopnet samples. Increased abundance of smaller HBC in shallower, near-shore habitat and increased abundance of larger juvenile HBC in deeper areas further from stream edge is consistent with findings by Gorman (1994) and Stone (1999) in their studies of HBC in the LCR. Our combination of minnow traps and hoopnets as complementary sampling units provided a more accurate representation of juvenile HBC size distribution than did the electrofish sampling. The increased abundance of adult RBT in electrofish samples suggests that RBT were relatively vulnerable to electroshock capture and that adult RBT were using shallow, near-shore habitats at night, possibly to prey on small fish that inhabit these areas.

Electrofishing and hoopnet-minnow trap sampling portrayed the distribution and abundance of RBT differently. While hoopnet-minnow trap sampling showed RBT to have seasonal peaks in abundance that paralleled juvenile HBC and varied considerably among sample reaches, electrofish sampling did not show these seasonal patterns and suggested that relative abundance of RBT was stable or increasing over time. In the HS-Carbon electrofishing reach, relative abundance of RBT was elevated in sampling periods when abundance of juvenile HBC was reduced (Figure 15), a pattern opposite of what was observed in hoopnet reaches. We suspect that some of these differences are artifacts of differences in sampling methods and some reflect important aspects of biology of the species.

In contrast to hoopnet-minnow trap samples, RBT was by far the predominant species in electrofish samples. Despite the reduced abundance of RBT in some subreaches and seasons in hoopnet-minnow trap samples, electrofishing samples showed nearly opposite or no reduction in RBT abundance in subreaches that overlapped with hoopnet-minnow trap sampling. This result supports the suggestion of an opportunistic predator response to increased abundance of prey (in this case seasonally abundant juvenile HBC) in some shallow, near-shore habitats.

The hoopnet sample subreaches were relatively discrete, small areas (~600 m) chosen to represent contrasting arrays of geomorphic shoreline types. For example, the Hopi-Salt subreach was comprised largely of talus-derived boulders. The Lava-Chuar and Tanner subreaches were composed mostly of vegetated sand and debris fan derived cobble shorelines. Electrofishing subreaches were large (~2-3 km) and incorporated a broader array of geomorphic shoreline types. Thus, some of the differences are related to differences in habitat and size of the sample subreaches. Our electrofishing samples are useful for showing general patterns, but have limited resolution in terms habitat association or spatial-temporal changes in distribution and abundance of fish.

We recognize that there were problems in comparing data from the two methods. The electrofishing sampling was not standardized, i.e., the same areas were not sampled among sampling periods and the effort per subreach was not consistent among the sampling trips. As we have seen from the hoopnet/minnow trap sampling, there can be substantial differences in species abundance and composition between subreaches. Electrofishing data had to be pooled over many sites to yield sample reaches of 1-2 km in length (and >1000 sec. minimum effort/sampling period) vs. 600 m for hoopnet sample subreaches. Thus, electrofish sampling had relatively low resolution and limited ability to show site-specific differences. Other factors that increased the variation in electrofish sampling were the timing of sampling relative to river stage (which fluctuated daily and changed dramatically on weekends), changing crews, and operational flaws in the electrofishing equipment.

To summarize, we suspect that differences in the portrayal of size composition, seasonal abundance, and distribution of juvenile HBC are related to differences in sampling design and biases inherent to the two sampling methods. Gorman (1994), Gorman and Stone (1999) and Stone (1999) demonstrated that hoopnets and minnow traps are highly effective in capturing HBC and characterizing size composition, movement, and habitat associations. Thus, it is likely that hoopnet-minnow trap samples accurately portray size composition and patterns of seasonal abundance of juvenile HBC in the MCR. Modification of electrofishing equipment and sampling design might reduce differences with hoopnet-minnow trap sampling.

Electrofishing boat design and operation

One operational flaw of the electrofishing boat was that it unintentionally targeted very small fish and large fish (especially RBT) in shallow water because of very narrow electric field propagation. This was caused by a lack of sufficient electrical continuity between the electrodes and the water and that only a single anode and cathode were used. This situation allowed use of higher voltage (up to 350V) in high-conductivity water (~900 μS/cm). Sparks were often observed at the point of connection of the anode to the boom (loose suspension link rather than a wired connection- OTG, pers. obs.). The electroshocking performance of the boat was evaluated by OTG, Robert Bramblett, Dennis Stone, and Randy VanHaverbeke on Lake Mohave in March 1999 while sampling razorback sucker (*Xyrauchen texanus)* in the flowing, clear tailwaters of Black Canyon at the upper end of the lake. Typical maximum output voltage was 300V for high resistance electrode connections and 150V for low resistance (high continuity) connections with one anode and two cathodes. Low resistance connections were made by connecting the electrodes to the booms with flexible copper cables and not relying on loose suspension links for electrical connection. With high resistance electrodes, the boat was only able to shock fish directly under the anode and when fish were <2 m away. The high clarity of the water facilitated the evaluation, and we had to chase fish to catch them with the narrow electric field. With low resistance electrodes, the boat was able to draw fish to the anode from a distance of 10 m. When used in shallow near-shore areas (<1 m depth) inhabited by small fish and occasional large fish, this electrofishing boat was relatively effective with high-resistance electrodes. However, in intermediate depth (>1 m) or deeper near-shore habitats, the boat was ineffective in capturing smaller fish unless they were near the surface (and the anode). In the LCR, larger juvenile HBC were associated with near-bottom positions in intermediate depth, structurally complex habitats while YOY HBC were found in shallower, near-shore areas in mid-water positions (Gorman 1994). If smaller HBC have similar habitat affinities in the Colorado mainstem, the electrofishing equipment would tend to be more efficient in capturing smaller YOY HBC and adult RBT in shallow, near-shore habitat and would be relatively inefficient in capturing larger juveniles in deeper, structurally complex habitats (where hoopnets work more efficiently to capture HBC). Although we realized that use of low resistance electrodes would improve the accuracy of sampling by the electrofishing boat, use of high resistance electrodes and one anode and one cathode were maintained for consistency throughout our study. For future MCR monitoring, we recommend modifying the design of the electrodes and their connections to improve continuity and electric field generation.

Future monitoring of juvenile HBC in the MCR

Our study of juvenile HBC in the LCR Inflow reach of the MCR used hoopnet-minnow trap sampling that was developed and used for many years to study HBC and other fishes in the LCR, the core habitat for the Grand Canyon HBC population (Gorman 1994, Gorman and Stone 1999, Stone 1999). We also used electrofish sampling in the LCR Inflow reach of the MCR and closely followed the methodology of Valdez and Ryel (1995) with the intent of maintaining continuity of data collection with early MCR studies (GCES Phase II, 1990-1996).

Sampling in the MCR was complemented by sampling in the LCR, the source area for juvenile HBC. Because we used hoopnet-minnow trap sampling in both areas, data were directly comparable because there are no inherent differences in gear bias. Electrofishing could not be done in the LCR because of the very high conductivity of the water (>5000 μS/cm at base flow). We recommend maintaining use of hoopnet-minnow trap sampling in both the LCR and MCR to monitor HBC populations in Grand Canyon. Use of hoopnet-minnow trap sampling may provide a more representative sample of juvenile HBC in the MCR and larger juveniles are not under-represented as they are in electrofishing samples. If electrofishing is to be used to monitor HBC populations in the MCR, sampling design, sampling protocols, and equipment design need modified and evaluated to assure that data are comparable to hoopnet-minnow trap samples. We believe that this can be accomplished by addressing the problems discussed previously. If habitat relationships, habitat use, and inter- and intra-specific interactions and direct comparison of ecological data with LCR sampling are of interest, hoopnet-minnow trap sampling will need to be used in future MCR studies.

Implications for dam operations, adaptive management, and recovery

Dispersal of YOY and larger juveniles from the LCR into the MCR appears to be caused or related to episodic late summer flooding in the LCR. The results of our study and that of Valdez and Ryel (1995) suggest that late summer downstream dispersal of YOY and larger juvenile HBC is a prominent biological feature of the LCR HBC aggregation. However, there appears to be little recruitment from these dispersing juvenile HBC in the MCR. If environmental conditions were more suitable in downstream reaches of the MCR, increased recruitment might be expected and this would lead to an increased abundance of HBC in the MCR.

Factors that cause low recruitment of juvenile HBC in the MCR are many. The most obvious factor is chronic low temperatures in the MCR (8-11°C), well below suitable temperatures for growth observed in the LCR (15-25°C) and in laboratory studies (Gorman and VanHoosen 2000, Clarkson and Childs 2000). In the MCR, cold temperatures cause small HBC to remain small and vulnerable to a large predator population. The second principal factor contributing to low recruitment is fluctuating flows caused by operation of Glen Canyon Dam. Daily fluctuating flows result in cyclic inundation and dewatering of shoreline habitats which in turn result in bank erosion, deterioration of shore line habitat, unstable microhabitats, reduced vegetative cover, and high rates of displacement and downstream movement of small fish. Chronic fluctuating flows are likely to suppress food resources for small fish by regular disturbance of shallow, near shore habitats that are usually very productive in most stream systems. The third principal factor contributing to low recruitment is the presence of a large cold-water predator population in the MCR. Stable, cold-water conditions in the MCR are ideal for supporting RBT populations as demonstrated by the presence of the prized RBT fishery in the upstream Lees Ferry reach. Despite the fluctuating flows, RBT thrive in the MCR, perhaps supported in part by dispersing small prey fish from warm-water tributaries. The combination of poor habitat conditions, cold water, daily disruption of microhabitat associations, loss of cover, and displacement from fluctuating flows and presence of a large predator trout population bode poorly for small HBC recruitment in the MCR.

Increased recruitment of small HBC in the MCR might be realized by changing the operation of Glen Canyon Dam. However, determining the correct operation that will benefit native fishes may be a daunting task. Just as the present operational paradigm has caused a multitude of effects on the MCR ecosystem in Grand Canyon, changes in that paradigm are likely to have many expected and unexpected consequences. Clearly, daily fluctuating flows and coldwater conditions are detrimental to recruitment of small HBC. Attempts to warm the MCR will have a negative impact on RBT and a positive impact on recruitment of small HBC. However, the MCR in Grand Canyon has a number of non-indigenous warmwater fishes that would also benefit and their success may prevent improvement of recruitment of small HBC. Developing a new operational paradigm for Glen Canyon Dam through adaptive management may be successful in finding a combination of management actions that will address the multitude of problems that thwart recruitment of HBC in the MCR in Grand Canyon.

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TABLE 1. Description of sampling trips within the Mainstem Colorado and Little Colorado Rivers, 1998-2000.

River	Sampling Reach	Date	Duration	Trip purpose
Mainstem Colorado	Lee's Ferry to Diamond Ck.	June 1998	16 days	Monitoring
Mainstem Colorado	Lee's Ferry to Diamond Ck.	Aug-Sept 1998	16 days	Monitoring
Mainstem Colorado	Lee's Ferry to Diamond Ck.	Jan-Feb 1998	14 days	Monitoring
Mainstem Colorado	Lee's Ferry to Diamond Ck.	June-July 1999	16 days	Monitoring
Mainstem Colorado	Lee's Ferry to Diamond Ck.	September 1999	16 days	Monitoring
Mainstem Colorado	Lee's Ferry to Diamond Ck.	January 2000	16 days	Monitoring
Little Colorado	Salt Camp	June 1998	3 days	Stable Isotope
Little Colorado	Salt Camp	July 1998	10 days	Monitoring
Little Colorado	Salt Camp	October 1999	10 days	Monitoring
Little Colorado	Salt Camp	April-May 1999	10 days	Monitoring
Little Colorado	Salt Camp	November 1999	10 days	Monitoring
Little Colorado	Confluence	March-Apr 1998	30+ days	Monitoring
Little Colorado	Confluence	March-May 1999	30+ days	Monitoring

TABLE 2. Fishing effort by trip date, gear type, and location among Mainstem Colorado River sampling trips during 1998-2000.

			LCR INFLOW SUB-REACHES		
Trip Date	**Gear Type**	**LCR Inflow** [a]	**Hopi-Salt**	**Lava Chuar**	**Tanner**
6/98	Electrofishing	3.7 hrs.			
8/98-9/98	Electrofishing	2.8 hrs.			
1/99-2/99	Electrofishing	2.9 hrs.			
6/99-7/99	Electrofishing	3.1 hrs.			
9/99	Electrofishing	3.2 hrs.			
1/00	Electrofishing	3.7 hrs.			
6/98	Hoopnets/Minnow Traps	1,730 hrs.	830 hrs.	900 hrs.	not sampled
8/98-9/98	Hoopnets/Minnow Traps	3,769 hrs.	1290 hrs.	1,189 hrs.	1290 hrs.
1/99-2/99	Hoopnets/Minnow Traps	3,889 hrs.	1,327 hrs.	1,320 hrs.	1,242 hrs.
6/99-7/99	Hoopnets/Minnow Traps	3,995 hrs.	1,235 hrs.	1,331 hrs.	1,429 hrs.
9/99	Hoopnets/Minnow Traps	3,901 hrs.	1,246 hrs.	1,305 hrs.	1,350 hrs.
1/00	Hoopnets/Minnow Traps	3,840 hrs.	1,240 hrs.	1,240 hrs.	1,360 hrs.

[a] Effort in the LCR Inflow reach is the sum of efforts within the Hopi-Salt, Lava Chuar, and Tanner sub-reaches.

TABLE 3. Summary of total hoopnet/minnow trap catch, LCR Inflow hoopnet subreaches, 1998-2000.

Species	*Species code*	*Hopi-Salt*	*Lava-Chuar*	*Tanner*	*Total*
		rm 63.3-63.8	rm 65.2-65.5	rm 68.0-68.5	rm 63.3-68.5
Humpback chub	HBC	133	94	51	**278**
Rainbow trout	RBT	22	110	145	**277**
Fathead minnow	FHM	2	16	13	**31**
Speckled dace	SPD	10	13	3	**26**
Bluehead sucker	BHS	3	2	3	**8**
Brown trout	BRT	2	1	4	**7**
Red shiner	RSH	1	1	1	**3**
Flannelmouth sucker	FMS	2	0	0	**2**
Common carp	CCP	0	2	0	**2**
Yellow bullhead	YBH	1	0	0	**1**
Channel catfish	CCF	0	1	0	**1**
Plains killifish	PKF	0	0	1	**1**
Total		**176**	**240**	**221**	**637**

TABLE 4. Summary of total electrofishing catch, LCR Inflow, electrofishing subreaches, 1998-2000.

Species	***Species code***	***ABLC-Crash***	***HS-Carbon***	***Tanner***	***Total***
		rm 60.0-62.8	rm 62.9-65.1	rm 66.8-68.5	rm 60.0-68.5
Humpback chub	HBC	8	104	42	**154**
Rainbow trout	RBT	270	257	132	**659**
Fathead minnow	FHM	3	38	6	**47**
Speckled dace	SPD	12	20	10	**42**
Brown trout	BRT	1	7	2	**10**
Red shiner	RSH	0	11	2	**13**
Flannelmouth sucker	FMS	10	1	0	**11**
Common carp	CCP	3	9	2	**14**
Total		**307**	**447**	**196**	**950**

TABLE 5. Mean juvenile humpback chub (JHBC; YOY plus larger juveniles) and rainbow trout (RBT) catch-per unit-effort (CPUE) by trip date and hoopnet-minnow trap sampling subreach in the Mainstem Colorado River (MCR), 1998-2000. CPUE units are fish captures per 100 hrs set time.

Trip Date	GEAR [a]	SITE	HBC CPUE	RBT CPUE
06/98	HN./M.T.	Hopi-Salt	0.16	0.216956
08/98-09/98	HN./M.T.	Hopi-Salt	1.73	0.083406
01/99-02/99	HN./M.T.	Hopi-Salt	0.30	0.127682
06/99-07/99	HN./M.T.	Hopi-Salt	0.50	0.131513
09/99	HN./M.T.	Hopi-Salt	2.91	0.278032
01/00	HN./M.T.	Hopi-Salt	0.18	0.178309
06/98	HN./M.T.	Lava Chuar	0.16	0.211829
08/98-09/98	HN./M.T.	Lava Chuar	3.09	1.728163
01/99-02/99	HN./M.T.	Lava Chuar	0.00	0.481173
06/99-07/99	HN./M.T.	Lava Chuar	0.22	0.29339
09/99	HN./M.T.	Lava Chuar	1.20	0.845046
01/00	HN./M.T.	Lava Chuar	0.11	0.931399
08/98-09/98	HN./M.T.	Tanner	0.65	1.629597
01/99-02/99	HN./M.T.	Tanner	0.09	0.490132
06/99-07/99	HN./M.T.	Tanner	0.46	0.581795
09/99	HN./M.T.	Tanner	0.41	2.4083
01/00	HN./M.T.	Tanner	0.21	0.80781
06/98	HN./M.T.	LCR Inflow	0.24	0.214612
08/98-09/98	HN./M.T.	LCR Inflow	1.63	0.973732
01/99-02/99	HN./M.T.	LCR Inflow	0.12	0.353855
06/99-07/99	HN./M.T.	LCR Inflow	0.39	0.32582
09/99	HN./M.T.	LCR Inflow	1.30	1.004918
01/00	HN./M.T.	LCR Inflow	0.17	0.604563

[a] HN./M.T. = Hoopnet/Minnow Trap.

TABLE 6. Juvenile humpback chub (JHBC; YOY plus larger juveniles) and rainbow trout (RBT) catch-per unit-effort (CPUE) by trip date and electrofishing subreach in the Mainstem Colorado River (MCR), 1998-2000. CPUE units are fish captures per hour electrofishing. CPUEs for LCR Inflow are from pooled data from Confluence, HS-Carbon, and Tanner electrofishing subreaches.

Trip Date	GEAR	SITE	CPUE HBC	CPUE RBT
06/98	Electrofishing	Confluence	0	49.177
08/98-09/98	Electrofishing	Confluence	0	59.865
01/99-02/99	Electrofishing	Confluence	3.174603	38.095
06/99-07/99	Electrofishing	Confluence	2.041974	61.259
09/99	Electrofishing	Confluence	5.973451	27.876
01/00			0	98.316
06/98	Electrofishing	HS-Carbon	7.568704	10.81
08/98-09/98	Electrofishing	HS-Carbon	26.52378	9.645
01/99-02/98	Electrofishing	HS-Carbon	4.544635	31.81
06/99-07/99	Electrofishing	HS-Carbon	6.924101	37.28
09/99	Electrofishing	HS-Carbon	16.26778	23.5
01/00	Electrofishing	HS-Carbon	3.905026	29.07
06/98	Electrofishing	Tanner		
08/98-09/98	Electrofishing	Tanner	36.50704	20
01/99-02/99	Electrofishing	Tanner	15.44328	12.063
06/99-07/99	Electrofishing	Tanner	8.534176	39.826
09/99	Electrofishing	Tanner	23.32613	95.896
01/00	Electrofishing	Tanner	0	73.127
06/98	Electrofishing	LCR Inflow	3.96	29.12
08/98-09/98	Electrofishing	LCR Inflow	18.73	30.48
01/99-02/99	Electrofishing	LCR Inflow	6.54	29.06
06/99-07/99	Electrofishing	LCR Inflow	6.51	41.69
09/99	Electrofishing	LCR Inflow	15.31	35.32
01/00	Electrofishing	LCR Inflow	2.52	49.00

TABLE 7. Association analysis of adult RBT and juvenile HBC from hoopnet-minnow trap samples. Expected values were generated from the binomial probability function, $(p + q)^2$. Critical X^2 value for 2 df and $p<0.05$: 5.991

	HBC	HBC+RBT	RBT	*N*	X^2 value
September 1998					
Hopi-Salt					
observed	18	0	2	20	NS
expected	16.2	3.6	0.2		
Lava-Chuar					
observed	11	13	3	27	NS
expected	9.7	13	4.3		
Tanner					
observed	5	4	13	22	7.08*
expected	2.6	10	9.4		
All sites pooled					
observed	34	17	18	69	15.661**
expected	24.1	32.6	11.2		
September 1999					
Hopi-Salt					
observed	18	4	2	24	NS
expected	15	8	1		
Lava-Chuar					
observed	10	5	7	27	6.30*
expected	6.9	10.8	4.3		
Tanner					
observed	2	6	15	29	NS
expected	1.8	9.3	11.9		
All sites pooled					
observed	30	15	24	69	21.73**
expected	19.8	34.3	14.9		

TABLE 8. Contingency Table Analysis of co-occurrence of adult RBT and juvenile HBC from hoopnet-minnow trap samples, LCR Inflow Reach, September 1998 and 1999. Critical X^2 value for 4 df and $p<0.05$: 9.488.

		HBC	**HBC+RBT**	**RBT**	***N***	**X^2 value**
September 1998						
Hopi-Salt						
	observed	18	0	2	20	
	expected	9.9	4.9	5.2		
Lava-Chuar						
	observed	11	13	3	27	
	expected	13.3	6.7	7		
Tanner						
	observed	5	4	13	22	
	expected	10.8	5.4	5.7		
Total		34	17	18	69	35.12***
September 1999						
Hopi-Salt						
	observed	18	4	2	24	
	expected	10.4	5.2	8.4		
Lava-Chuar						
	observed	10	5	7	22	
	expected	9.5	4.8	7.7		
Tanner						
	observed	2	6	15	23	
	expected	10	5	8		
Total		30	15	24	69	23.27***

FIGURE 1. Size composition of HBC and RBT from hoopnet/minnow trap subreaches, LCR Inflow, 1998-2000. Subreaches: Hopi-Salt, Lava-Chuar, Tanner.

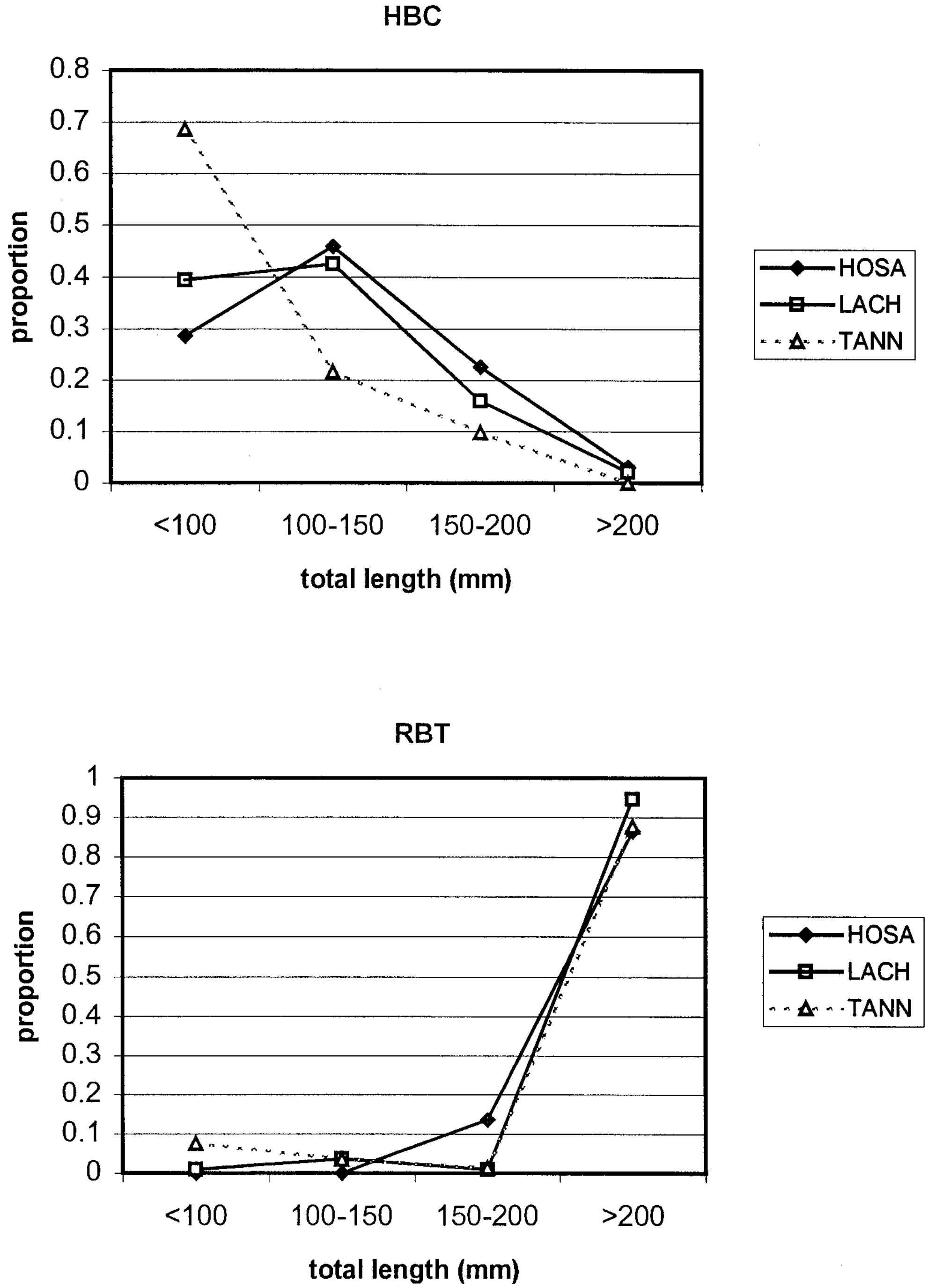
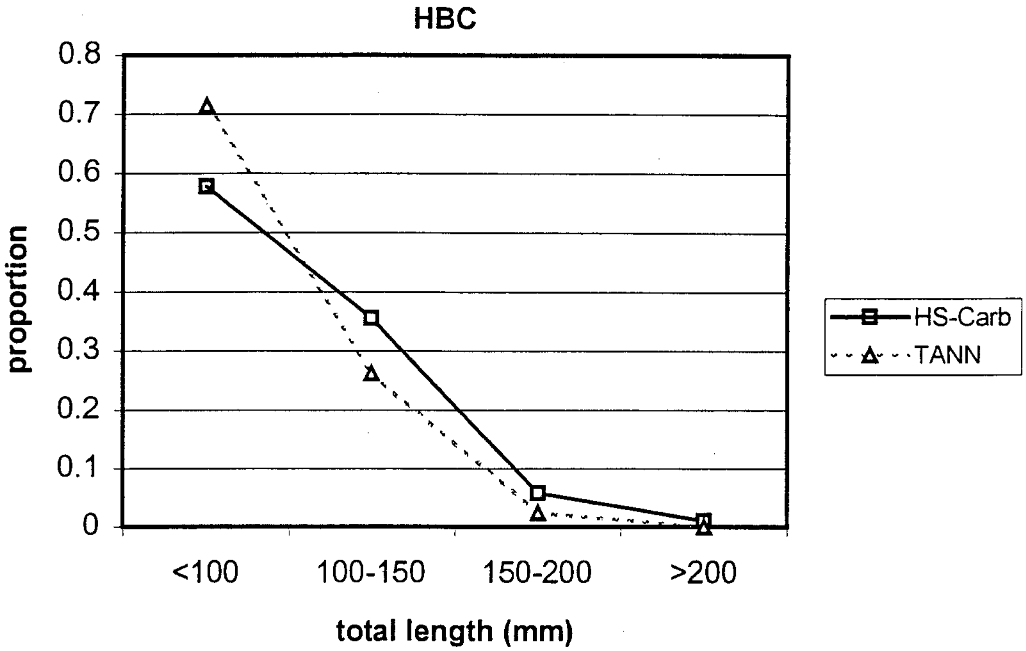


FIGURE 2. Size composition of HBC and RBT from electrofishing subreaches, LCR Inflow, 1998-2000. Electrofishing subreaches: ABLC-Crash, H-S Carbon, Tanner.



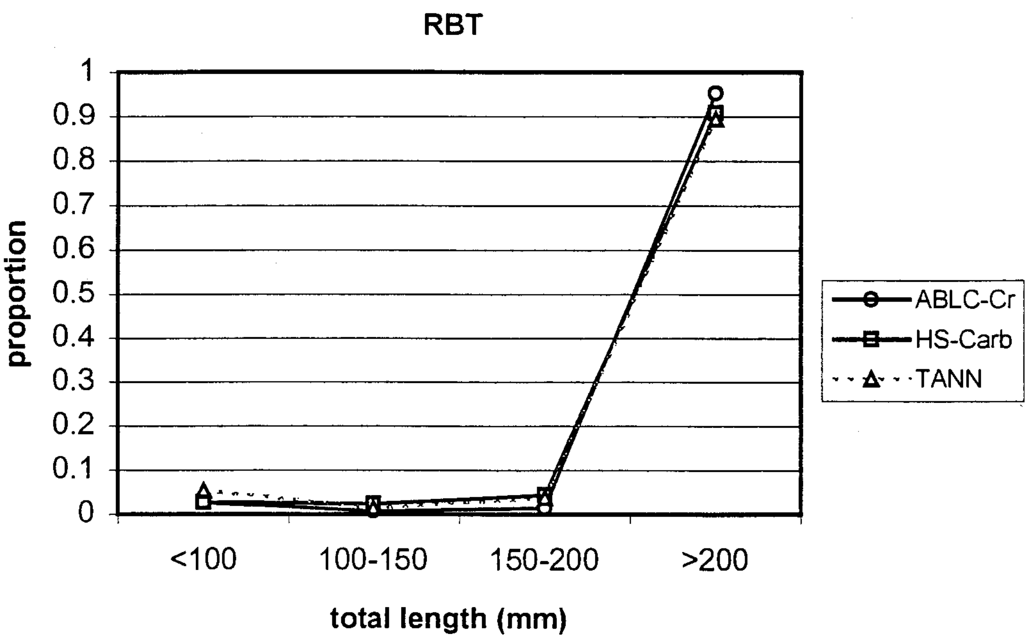
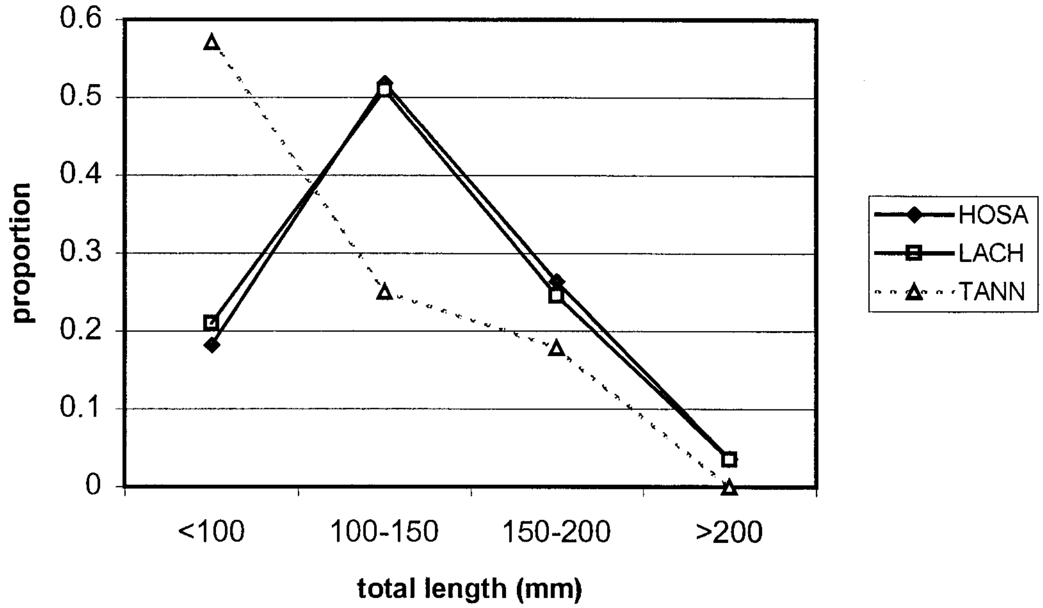


FIGURE 3. Comparison of size composition of HBC from hoopnets and minnow traps from the LCR Inflow subreaches, 1998-2000.

Size composition of HBC caught in hoopnets



Size composition of HBC caught in minnow traps

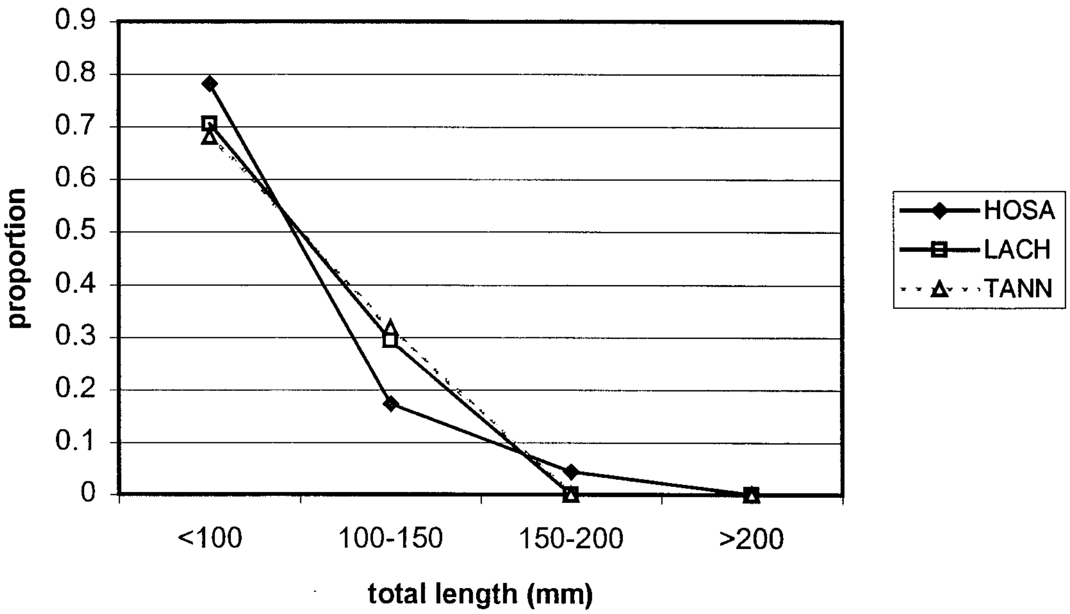


FIGURE 4. Summary of hoopnet-minnow trap and electroshock sampling of HBC (YOY and larger juveniles, L-J) in the LCR inflow, 1998-2000.

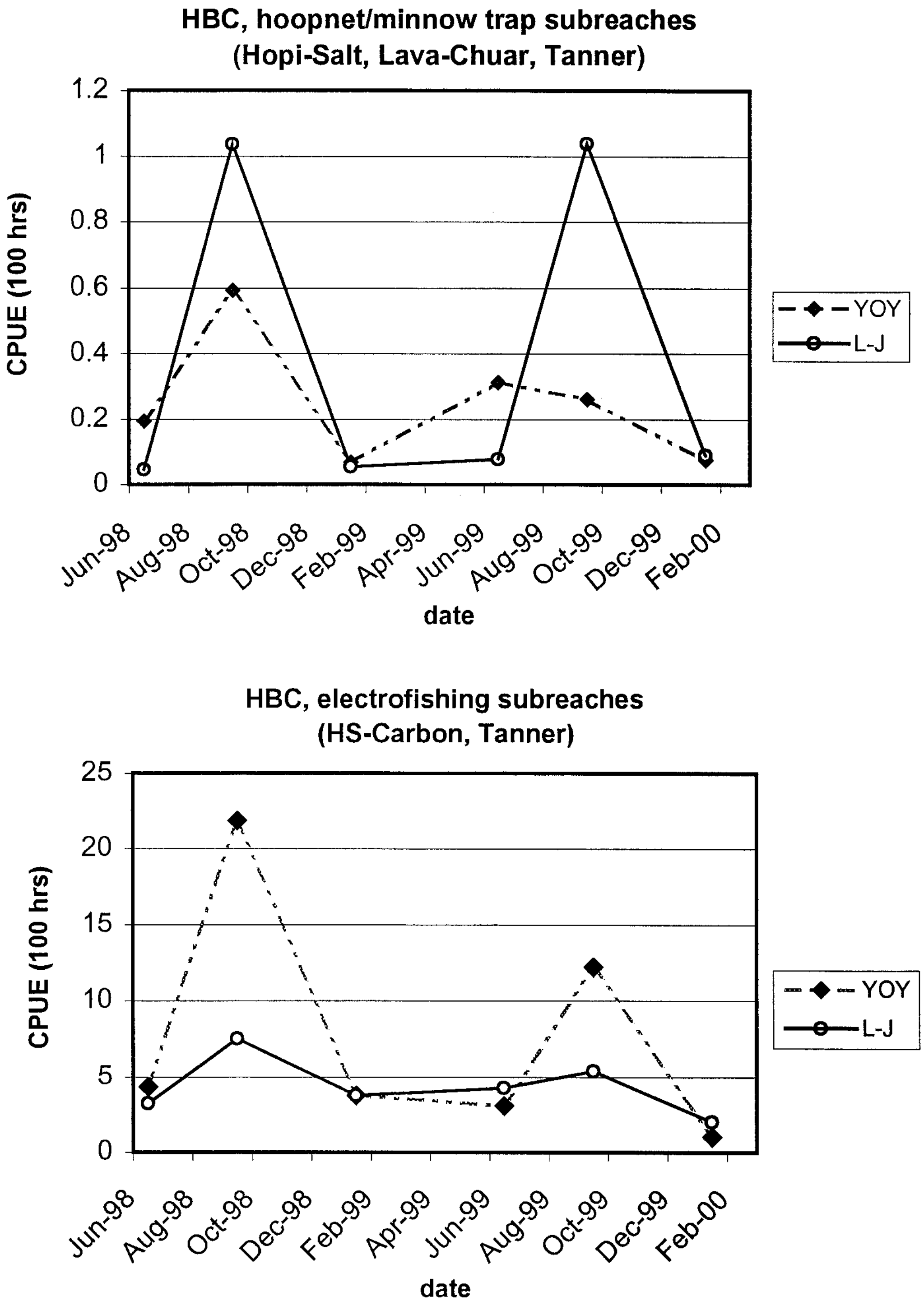


FIGURE 5. Abundance of juvenile HBC (YOY and larger juveniles, LJ), in hoopnet/minnow trap samples by subreach, LCR Inflow, 1998-2000.

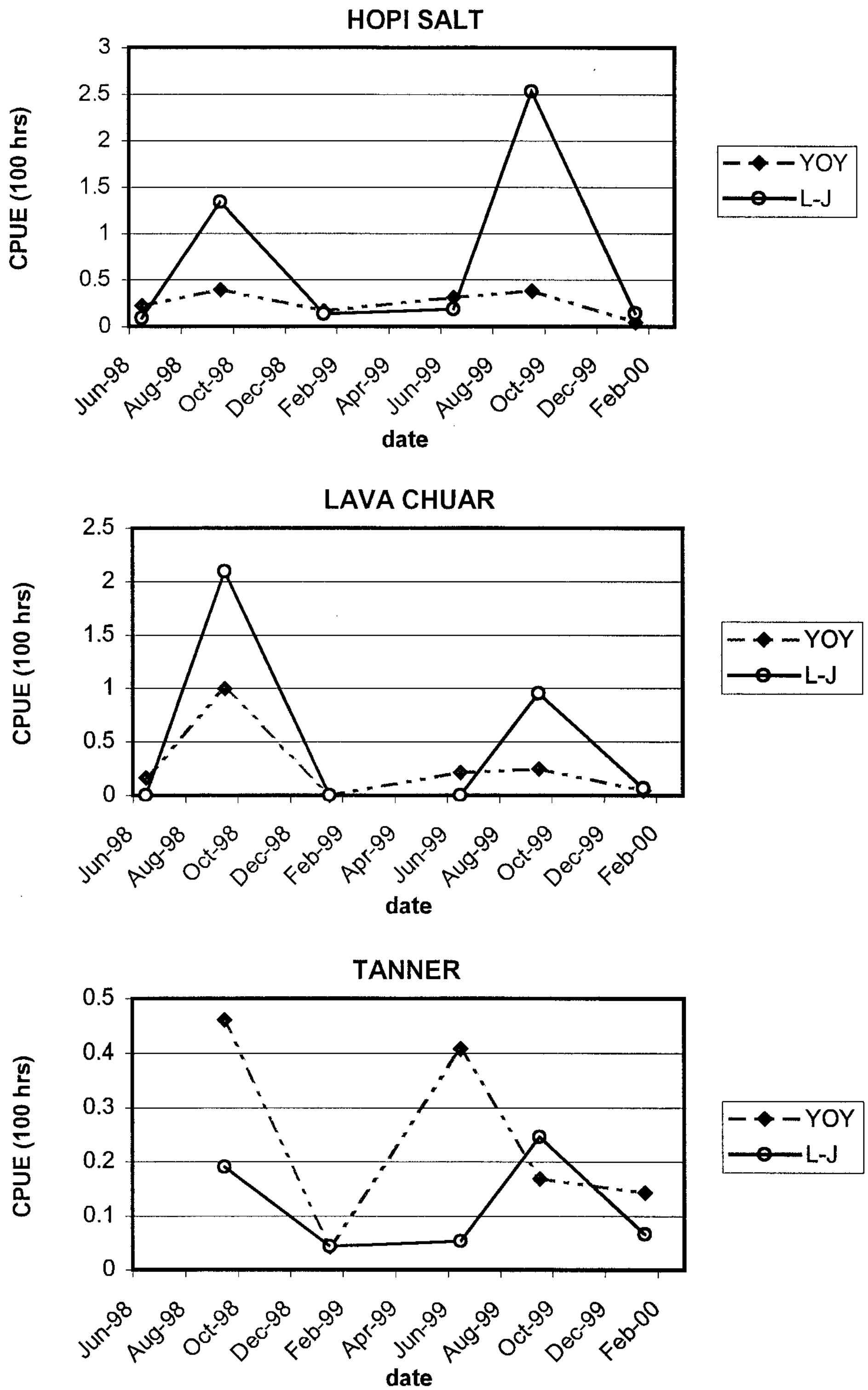
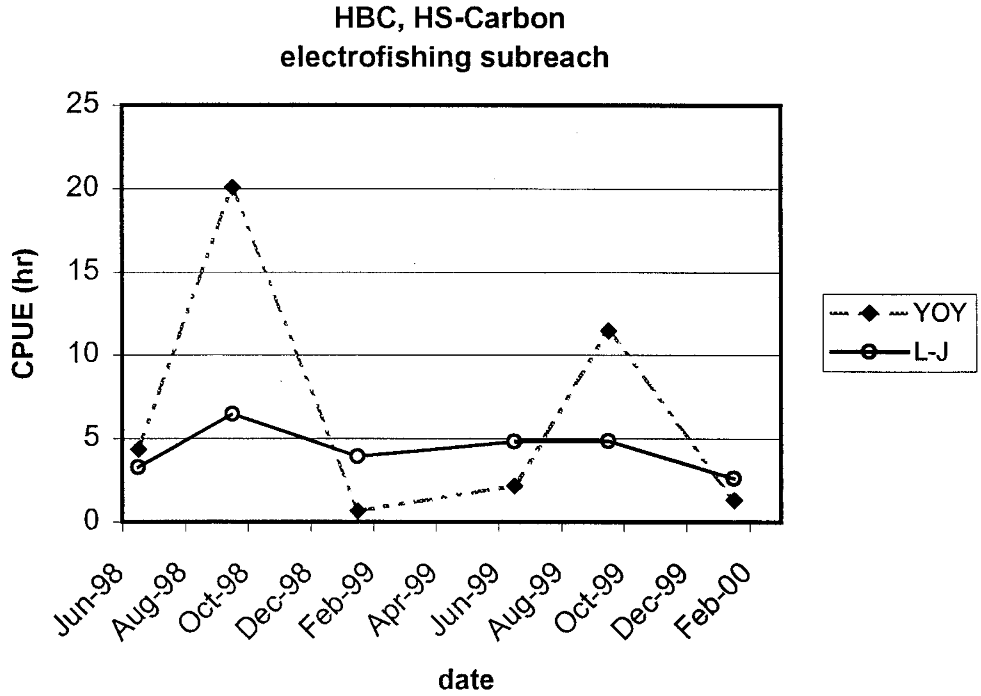


FIGURE 6. Abundance of juvenile HBC (YOY and larger juveniles, L-J) in electrofishing samples by subreach, LCR Inflow, 1998-2000.



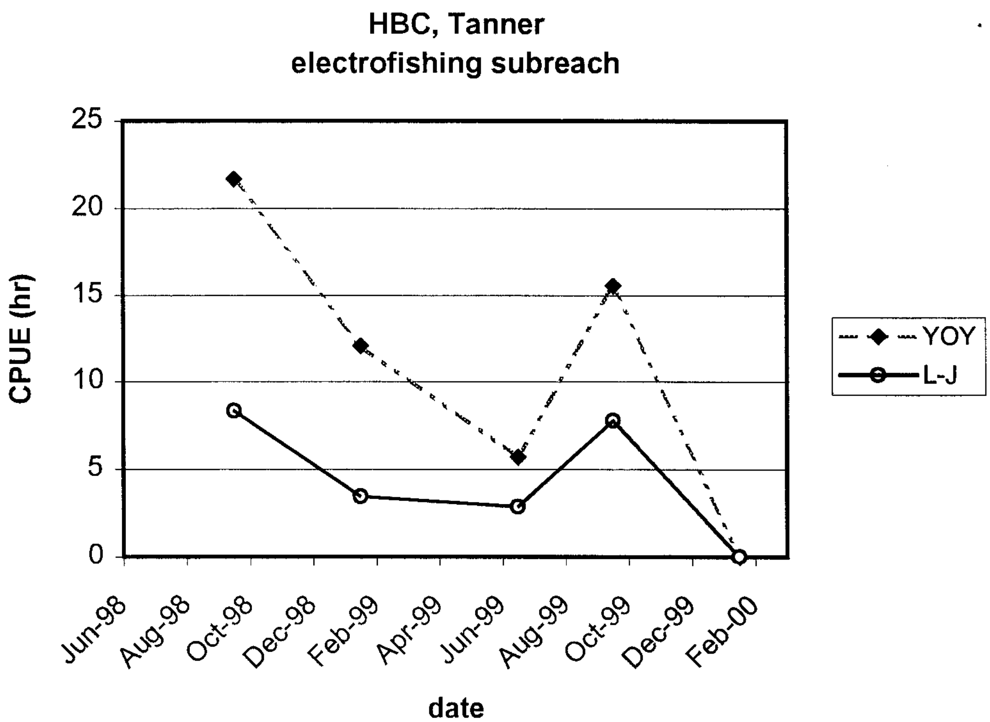


FIGURE 7. Summary of hoopnet/minnow trap sampling, HBC (YOY and larger juveniles, L-J), LCR Inflow Sites, 1998-2000.

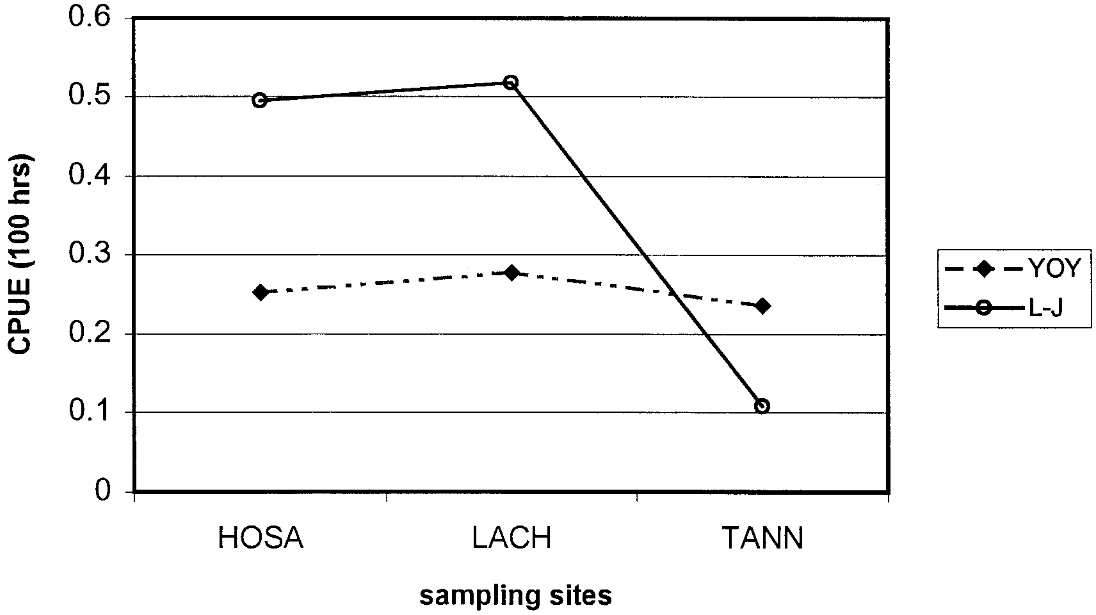


FIGURE 8. Summary of hoopnet/minnow trap sampling, HBC (YOY and larger juveniles, L-J), seasonal CPUE, LCR Inflow, 1998-2000.

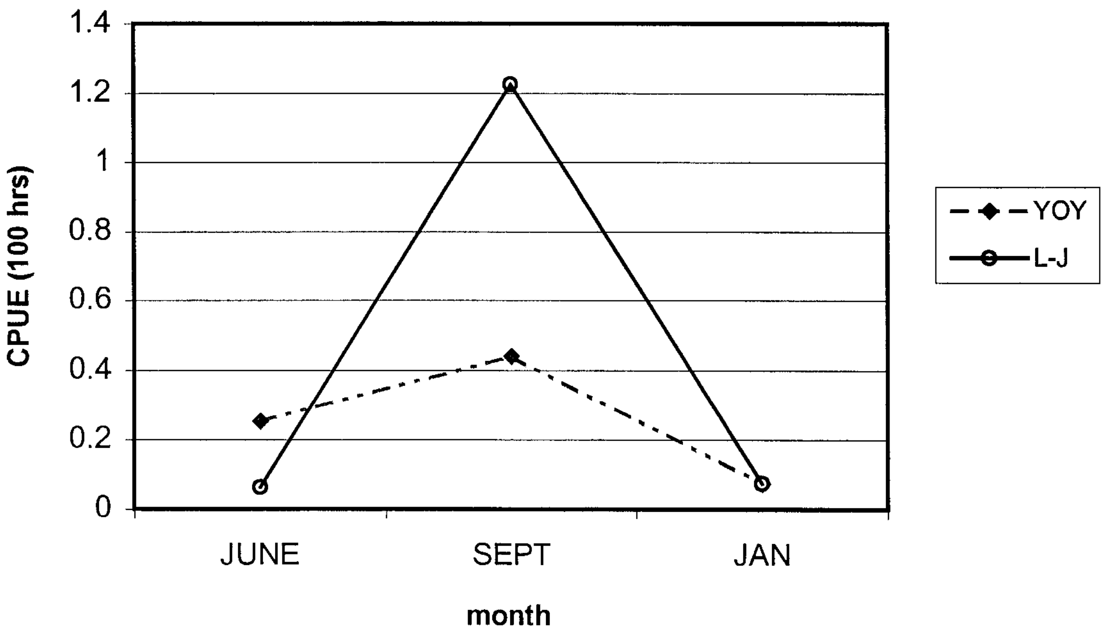
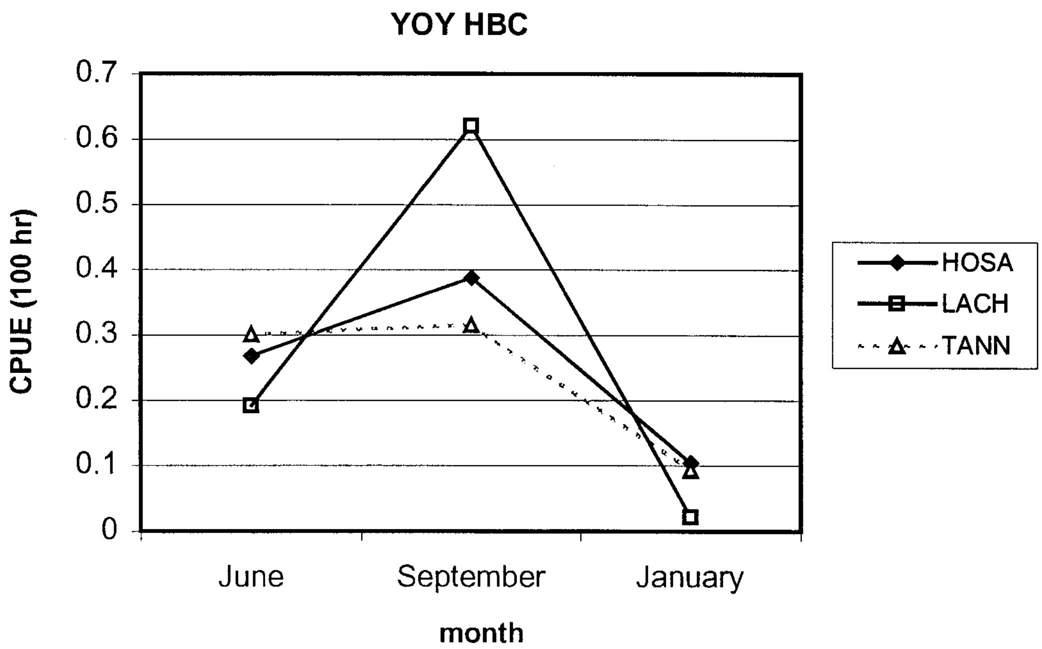


FIGURE 9. Seasonal CPUE of HBC from hoopnet/minnow trap subreaches, LCR Inflow, 1998-2000.



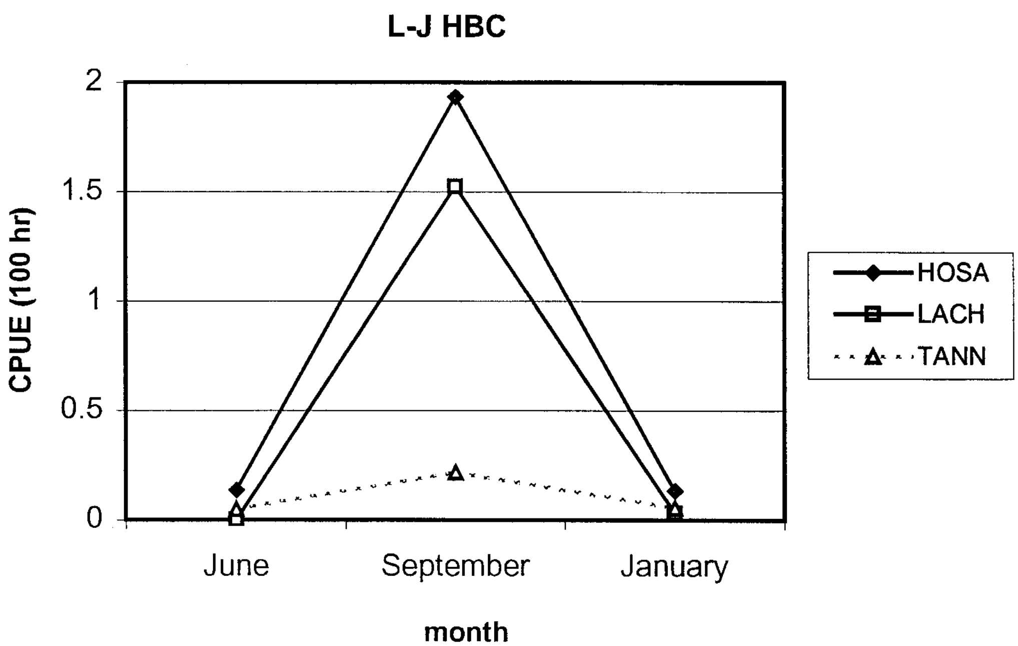
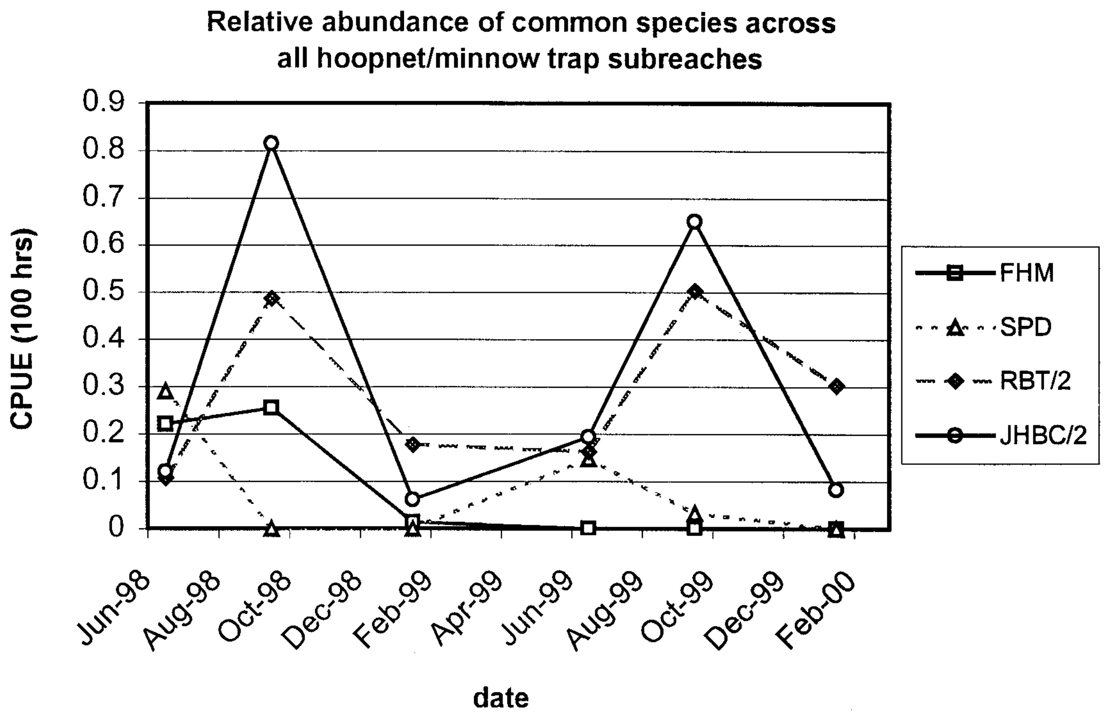


FIGURE 10. Relative abundance of common species in hoopnet/minnow trap subreaches, LCR Inflow, 1998-2000.



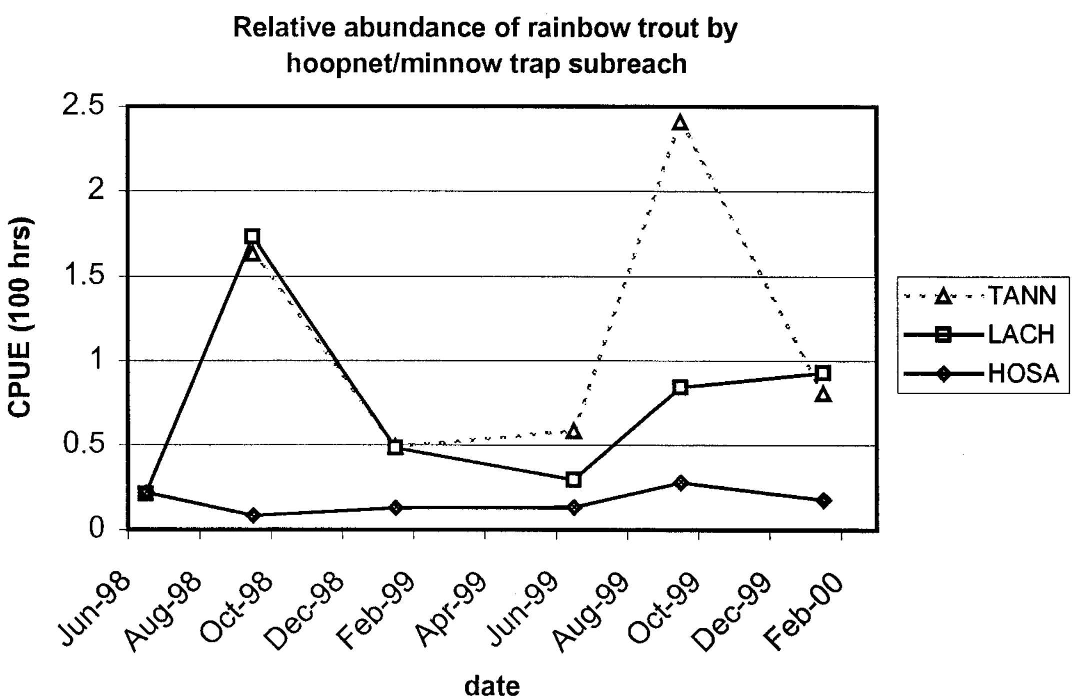
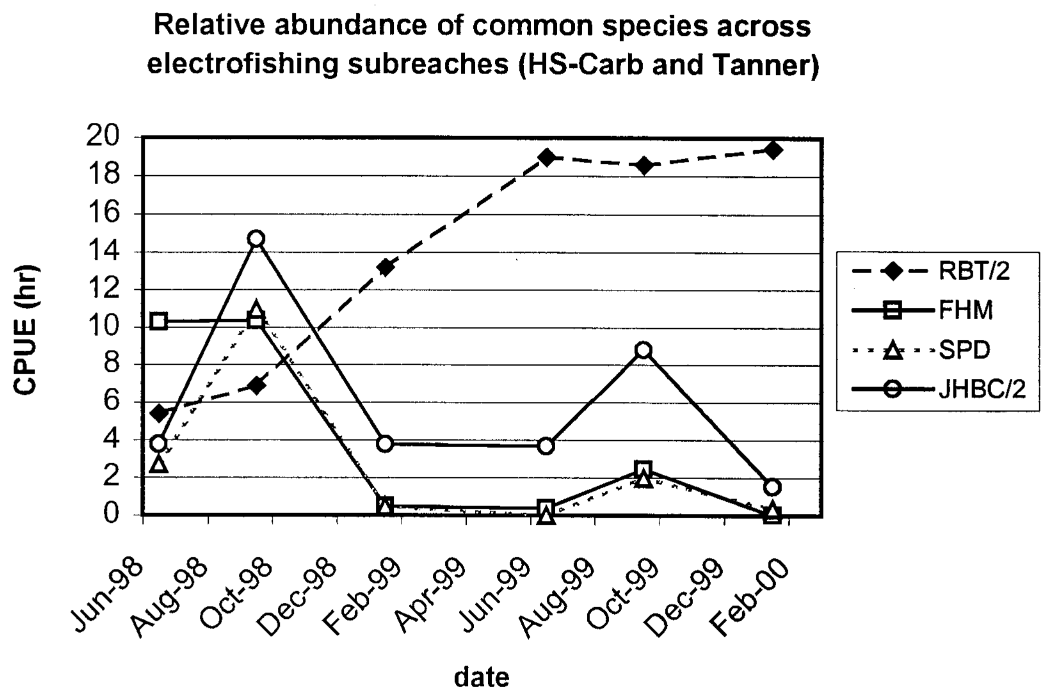


FIGURE 11. Relative abundance of common species in the electrofishing subreaches, LCR Inflow, 1998-2000.



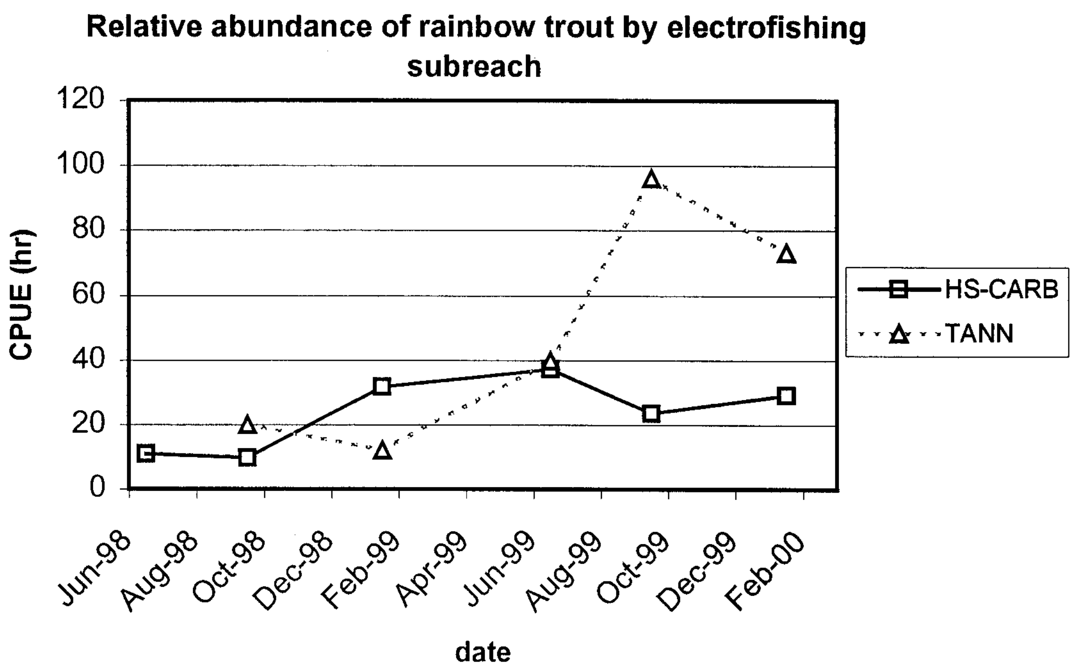
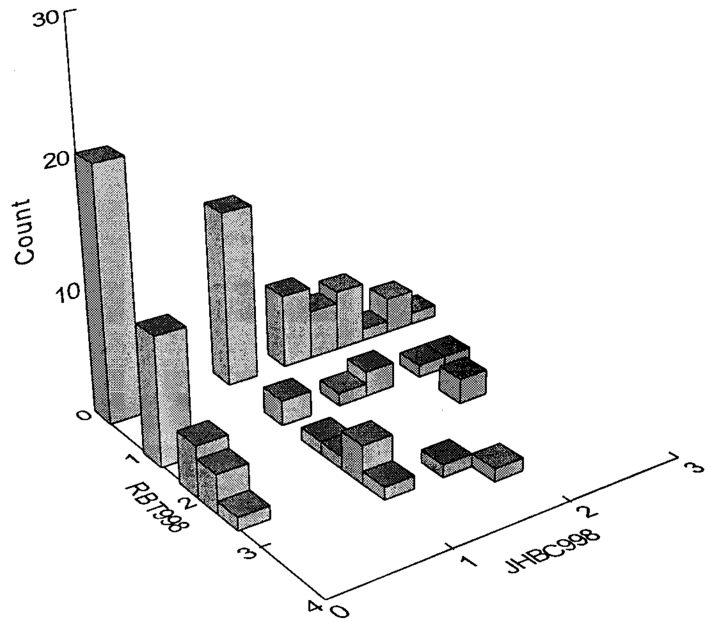
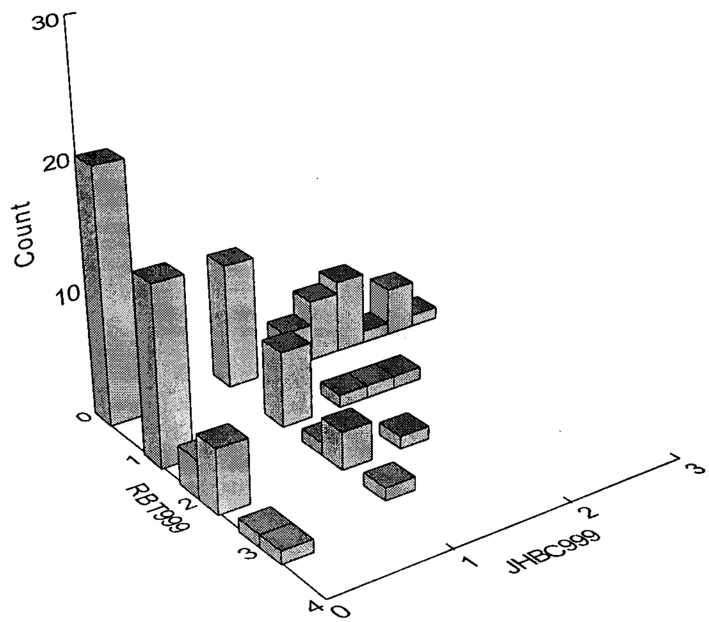


FIGURE 12. Occurrence of JHBC and RBT at hoopnet/minnow trap sample locations in the Hopi-Salt, Lava-Chuar, and Tanner subreaches of the LCR Inflow of the Colorado River in September 1998 and 1999.



September 1998



September 1999

FIGURE 13. Summary of RBT and HBC catch from hoopnet/minnow traps, LCR Inflow, 1998-2000.

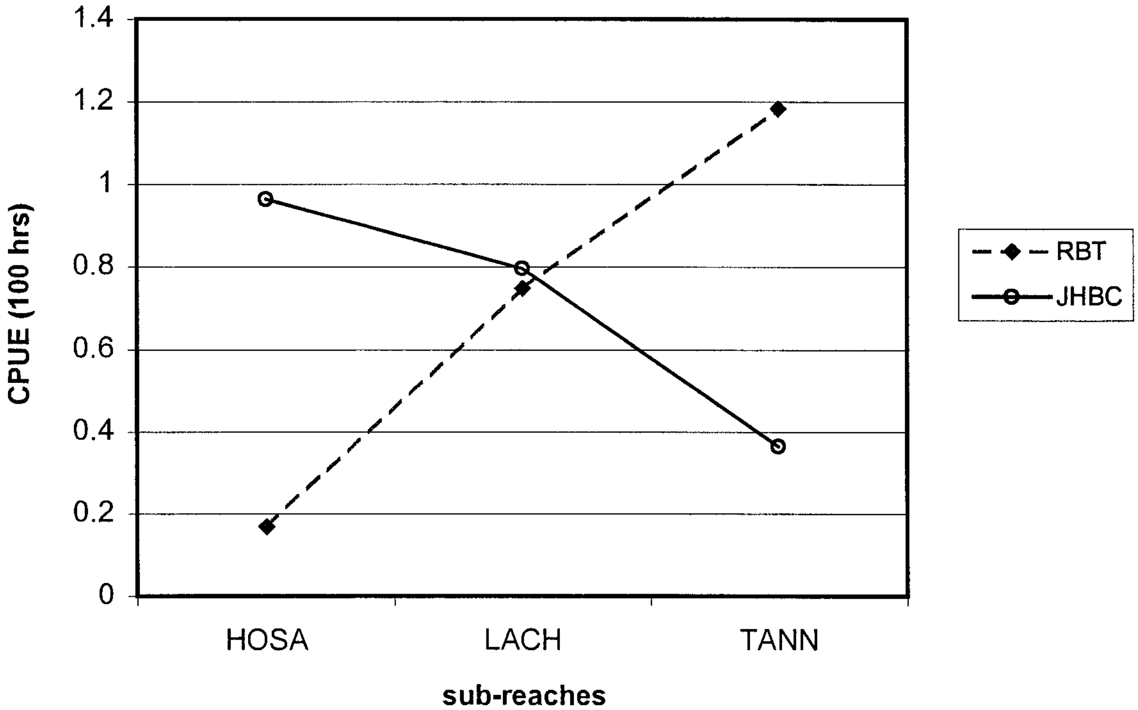


FIGURE 14. Seasonal abundance of RBT and HBC in hoopnet/minnow trap subreaches, LCR inflow, 1998-2000.

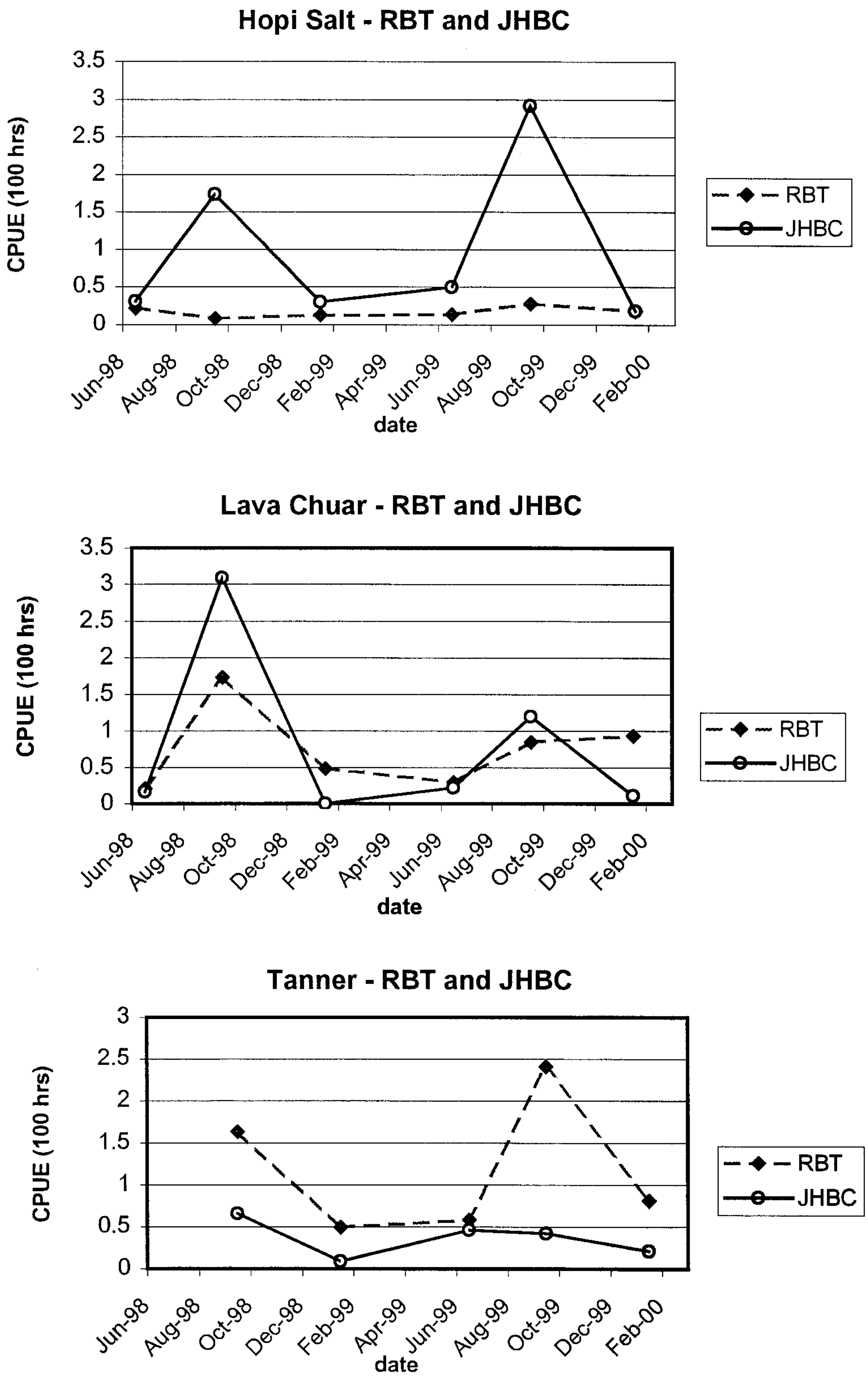
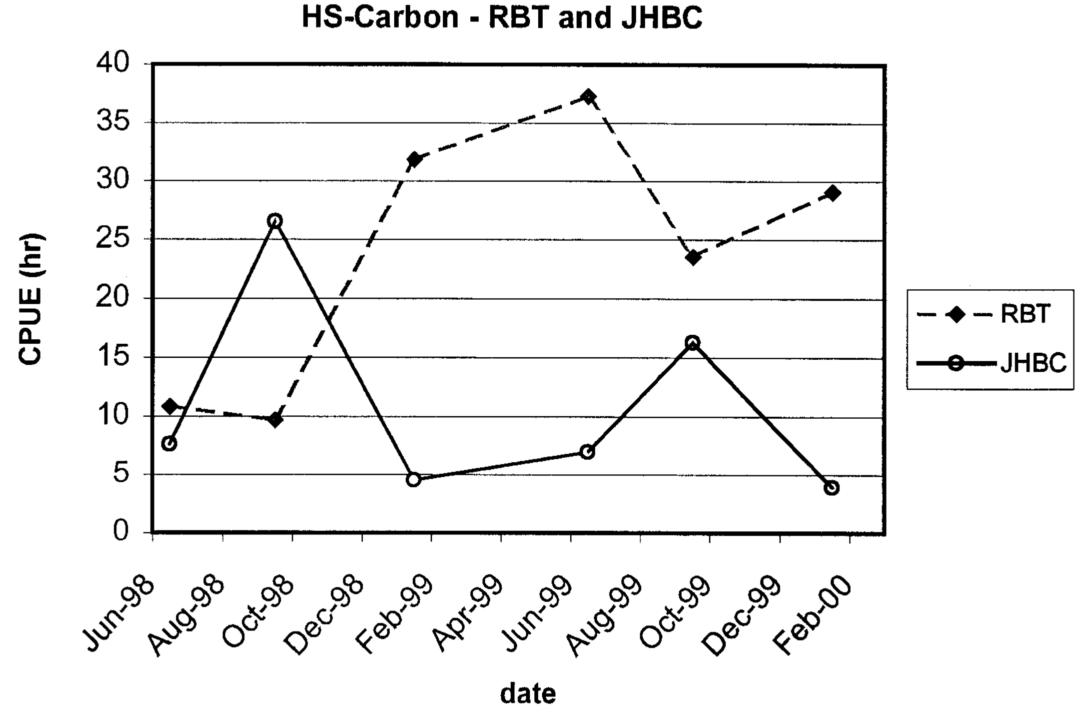


FIGURE 15. Seasonal abundance of RBT and HBC in electrofishing subreaches, LCR inflow, 1998-2000.



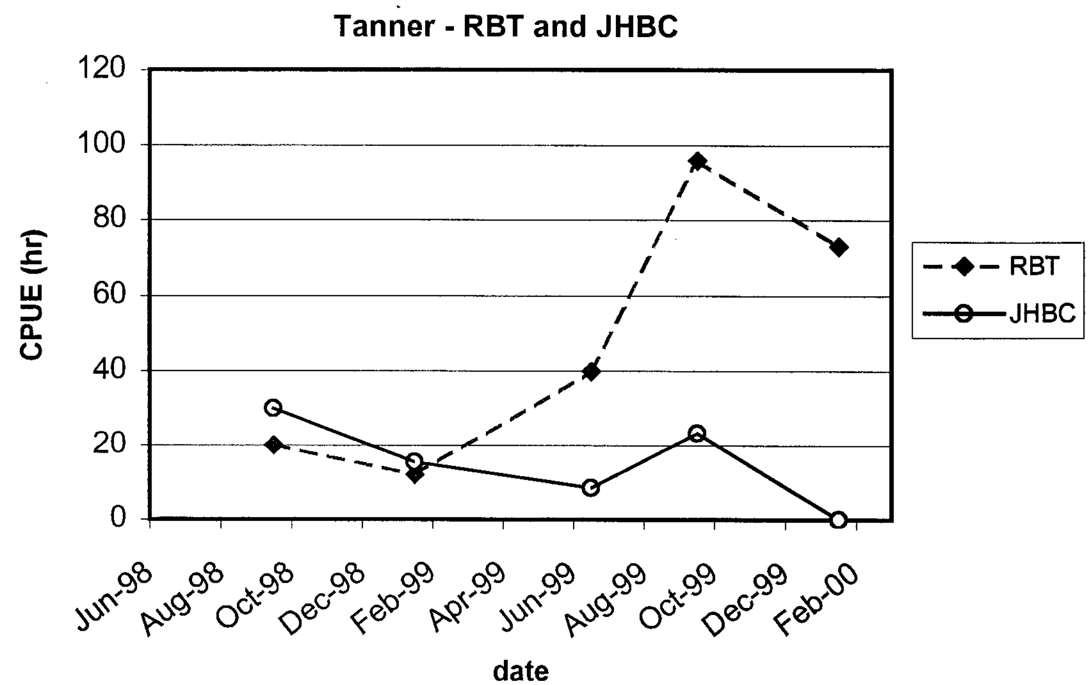
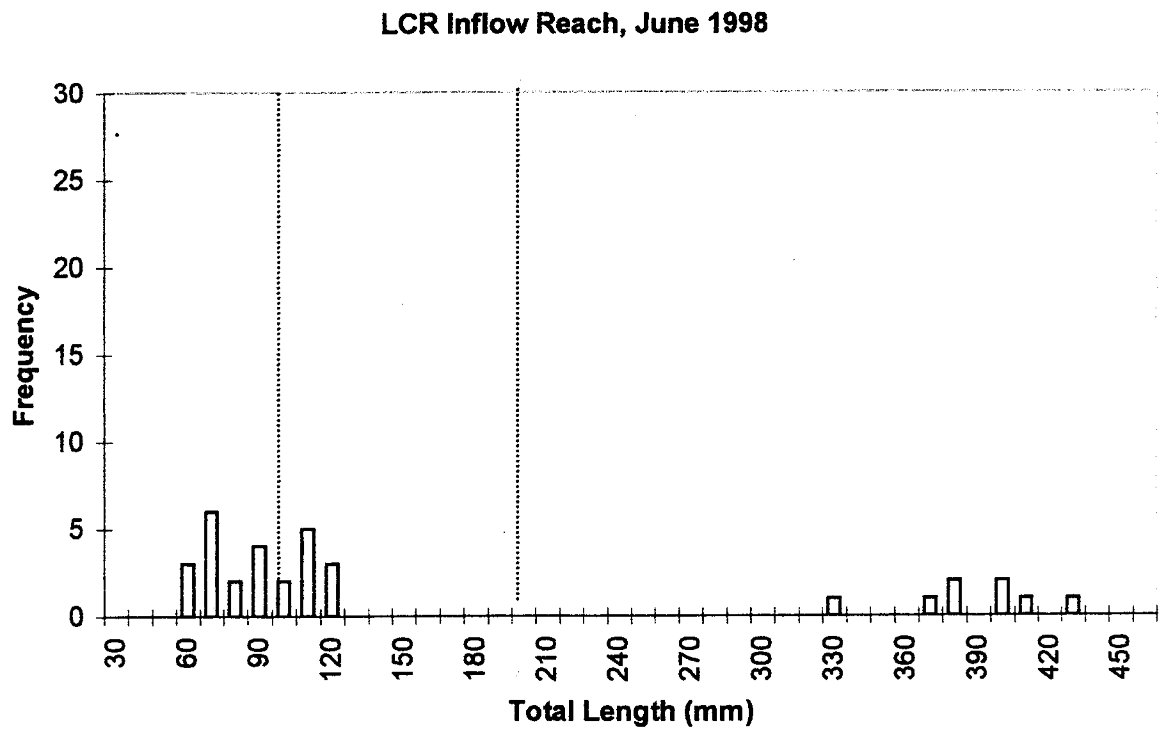


Figure 16. Length-frequency distributions of humpback chub caught in the LCR and LCR Inflow Reach in summer of 1998. Vertical dotted lines at 100 and 200 mm TL are provided for reference.



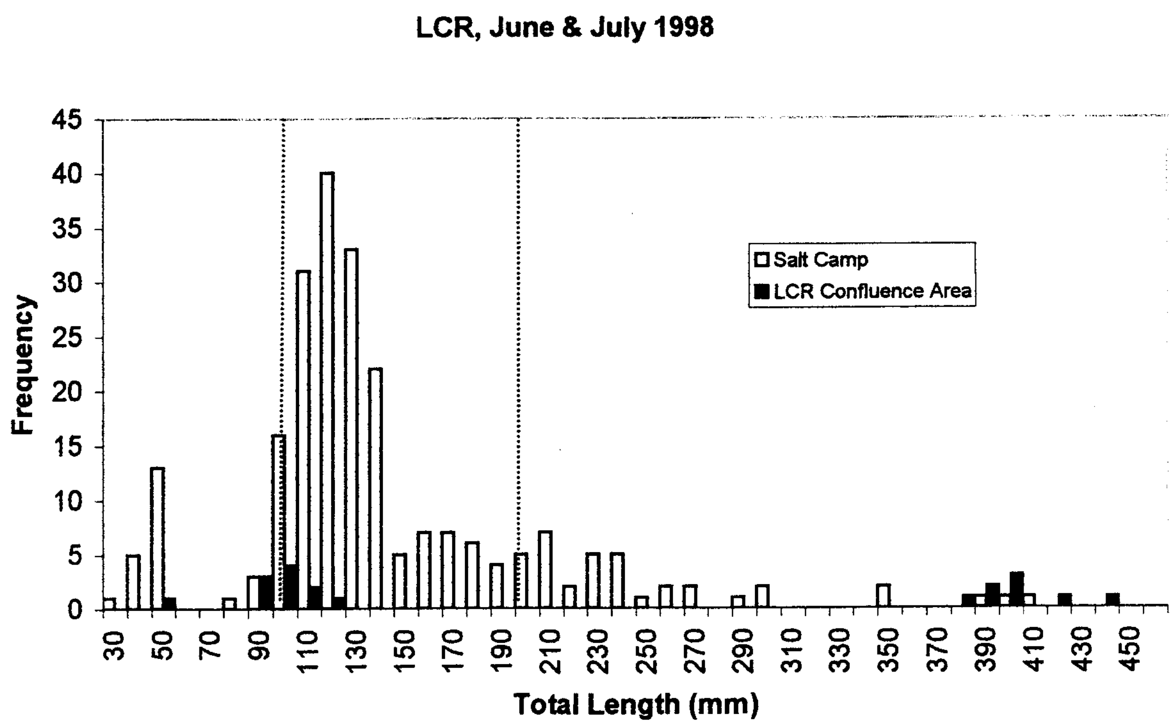
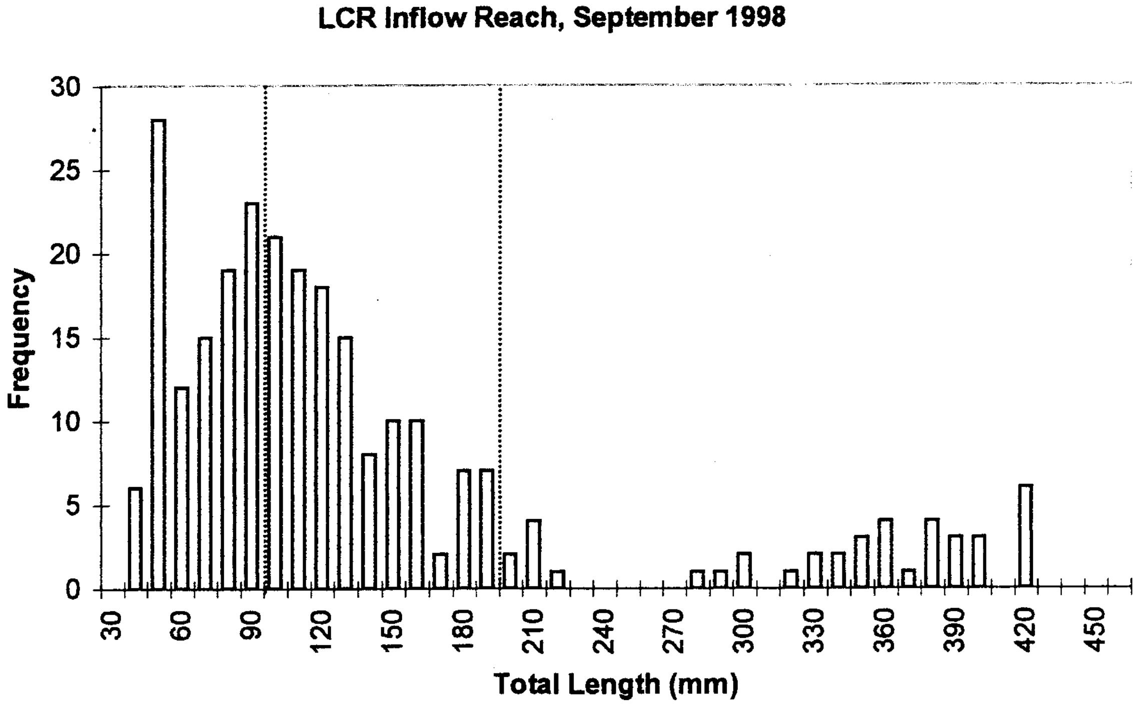


Figure 17. Length-frequency distributions of humpback chub caught in the LCR and LCR Inflow Reach in fall of 1998. Vertical dotted lines at 100 and 200 mm TL are provided for reference.



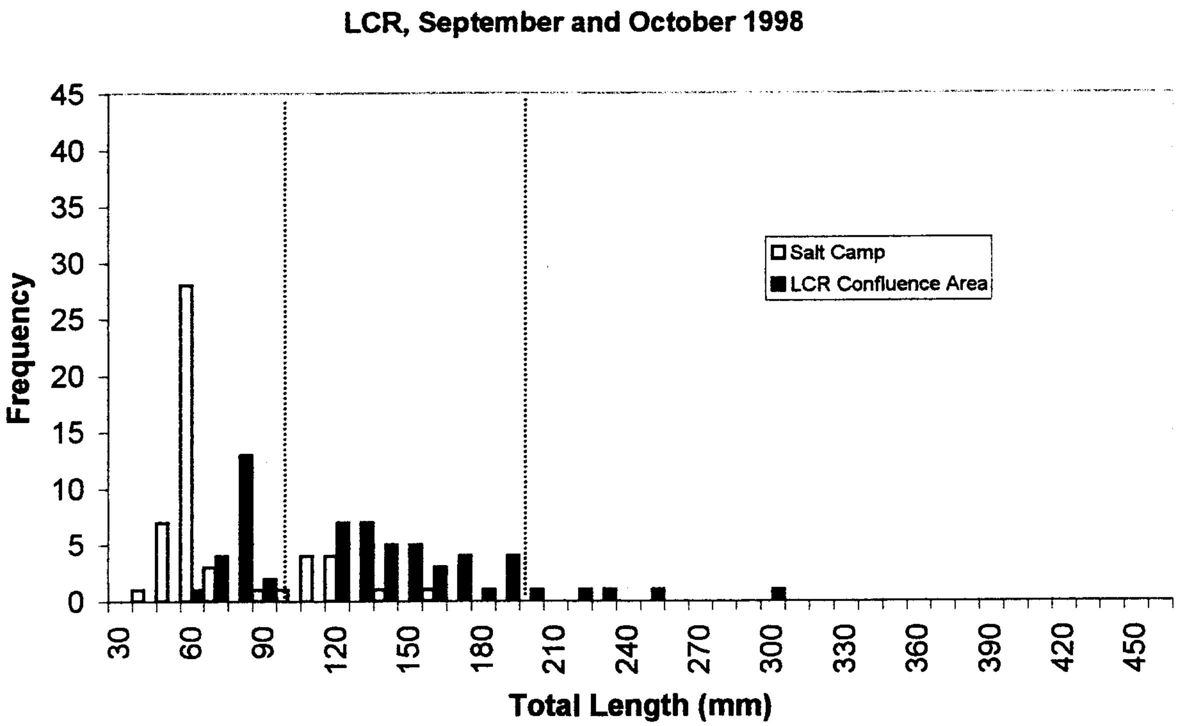
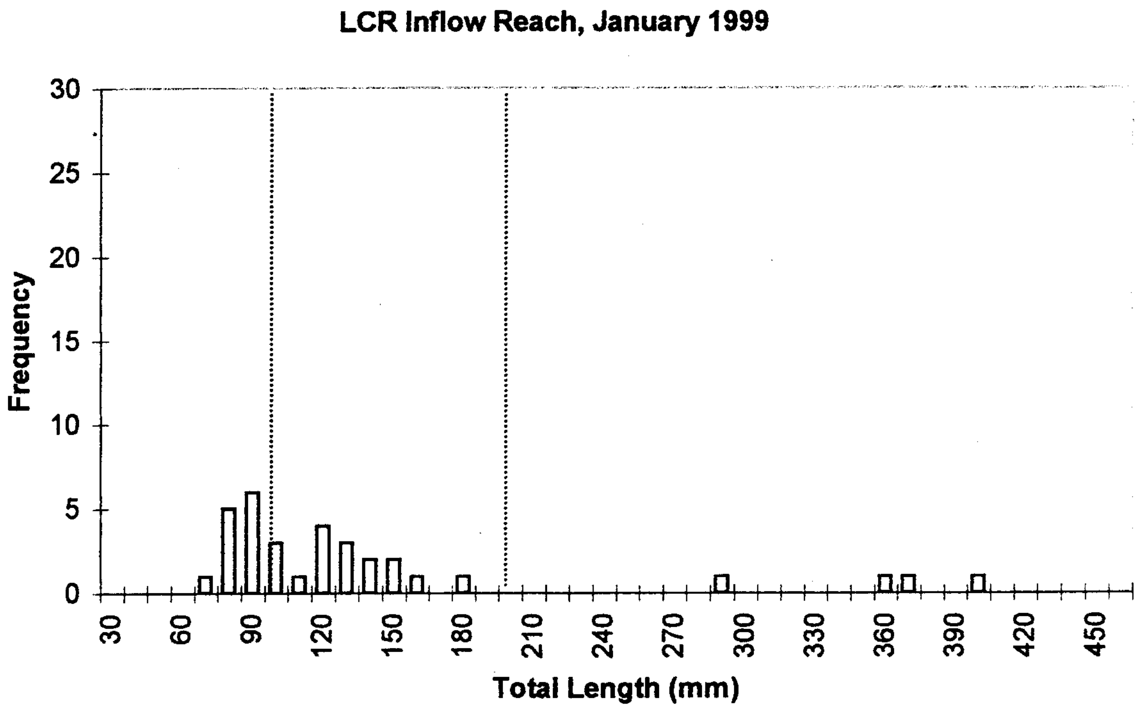


Figure 18. Length-frequency distributions of humpback chub caught in the LCR and LCR Inflow Reach in winter of 1999. Vertical dotted lines at 100 and 200 mm TL are provided for reference.



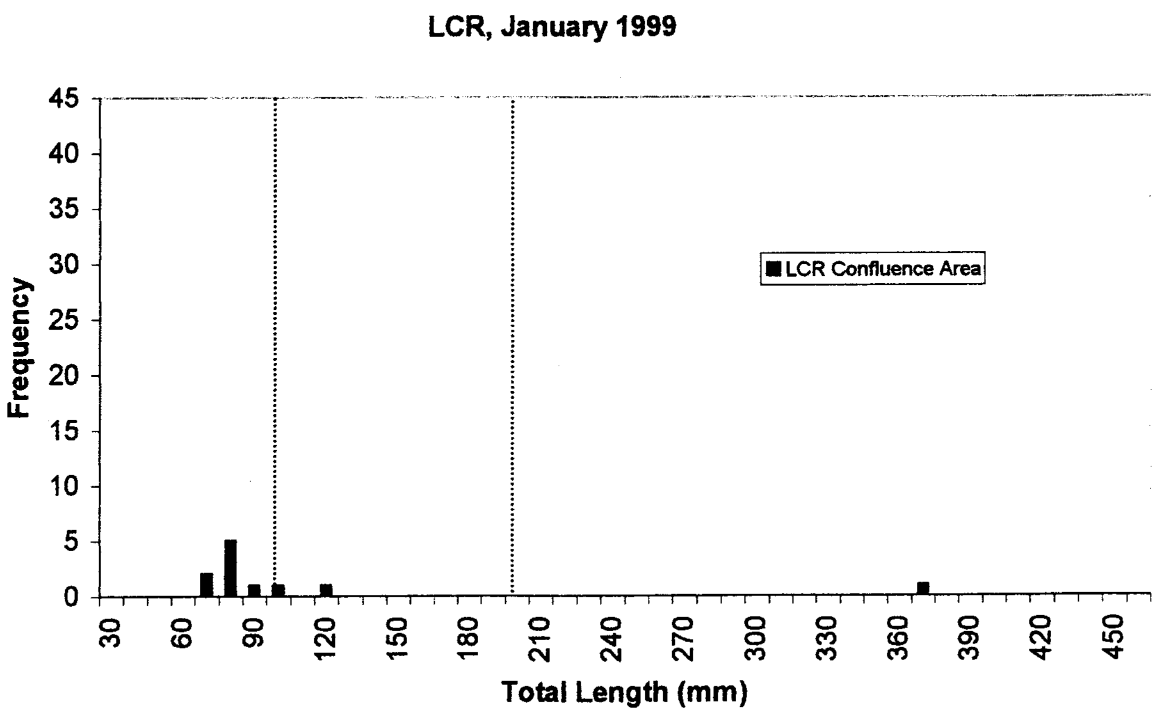
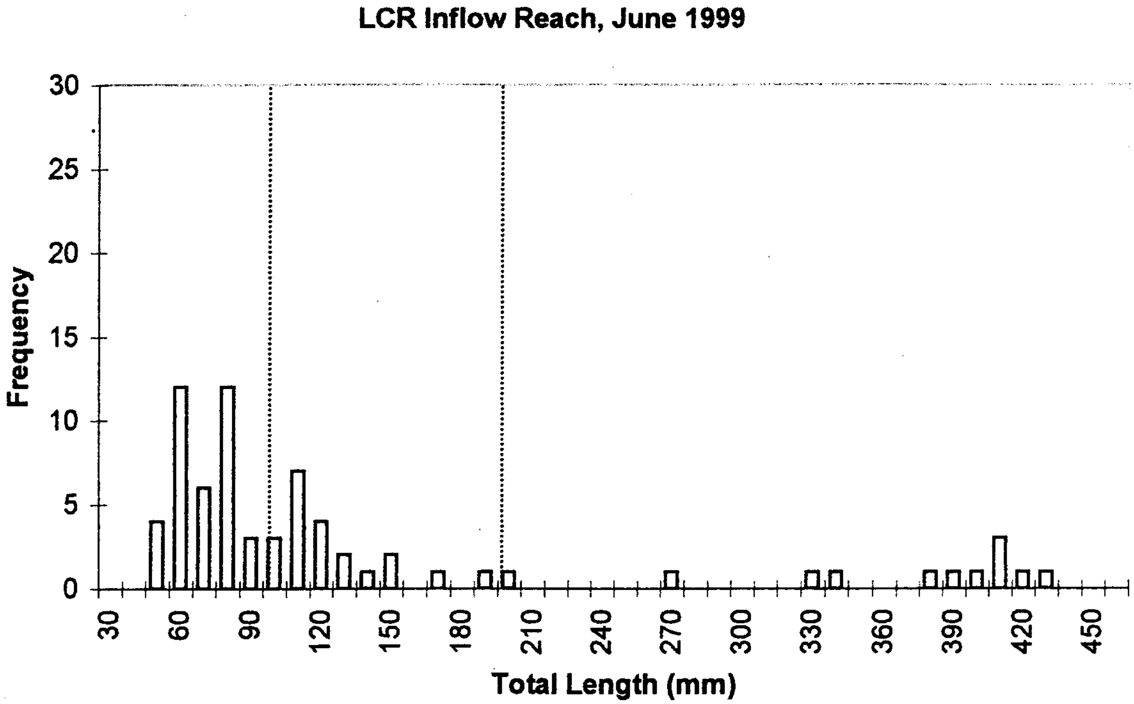


Figure 19. Length-frequency distributions of humpback chub caught in the LCR and LCR Inflow Reach in spring and summer of 1999. Vertical dotted lines at 100 and 200 mm TL are provided for reference.



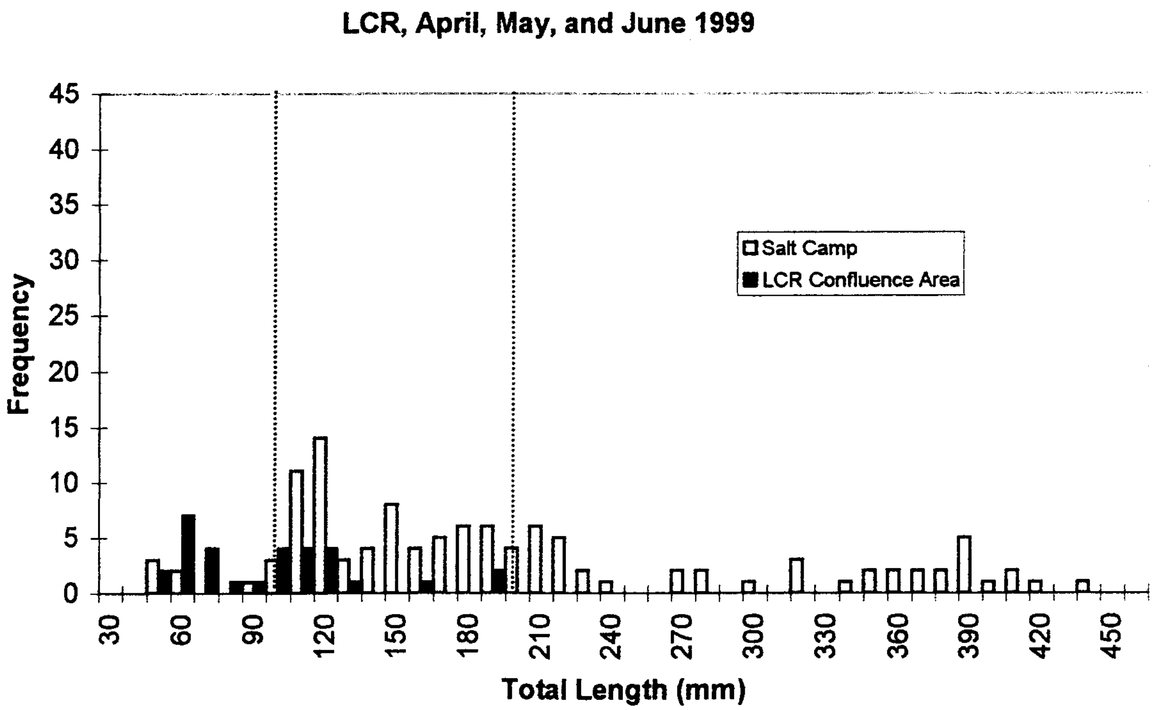
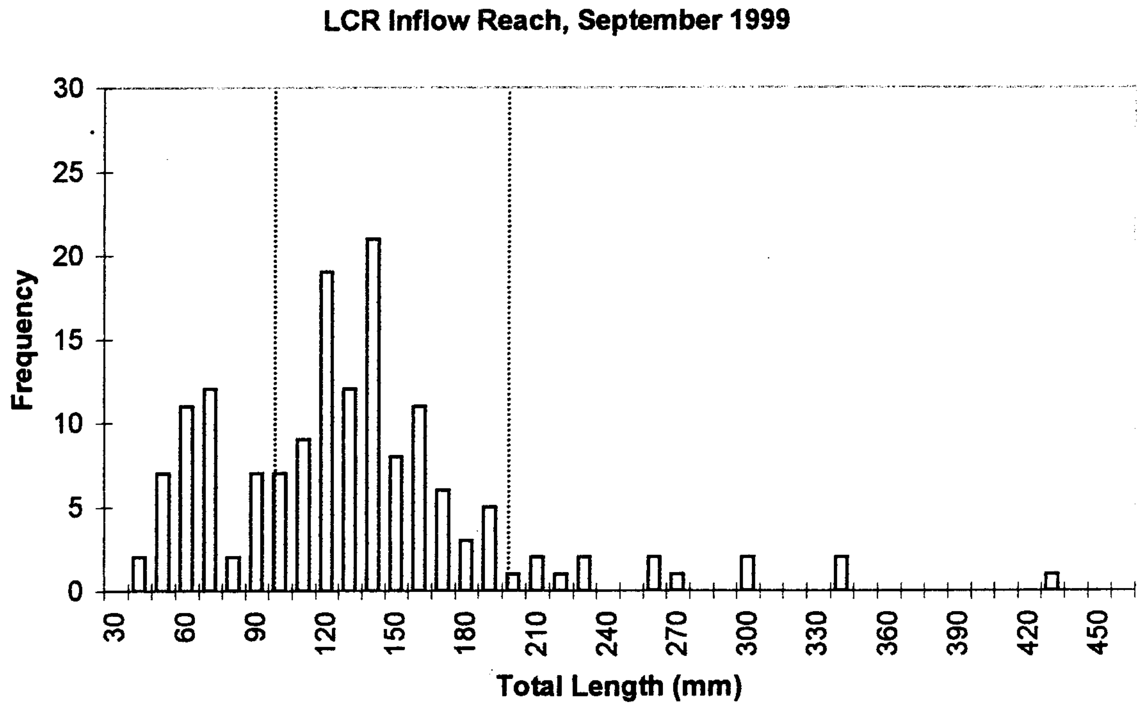


Figure 20. Length-frequency distributions of humpback chub caught in the LCR and LCR Inflow Reach in fall of 1999. Vertical dotted lines at 100 and 200 mm TL are provided for reference.



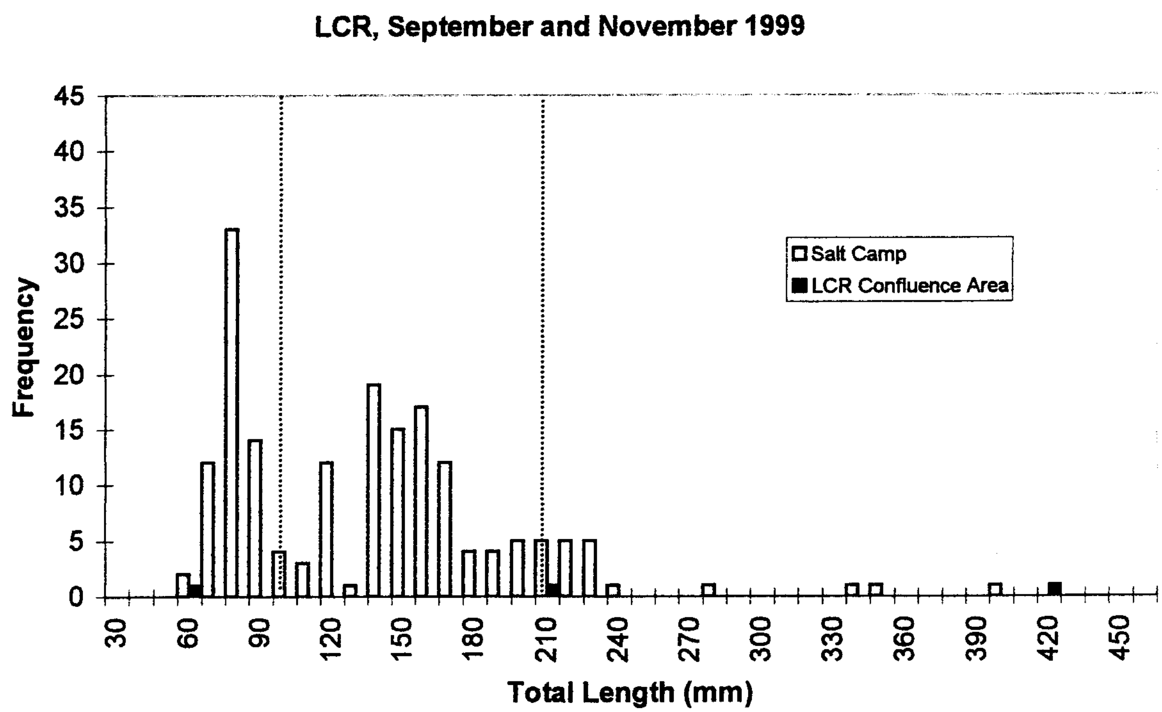
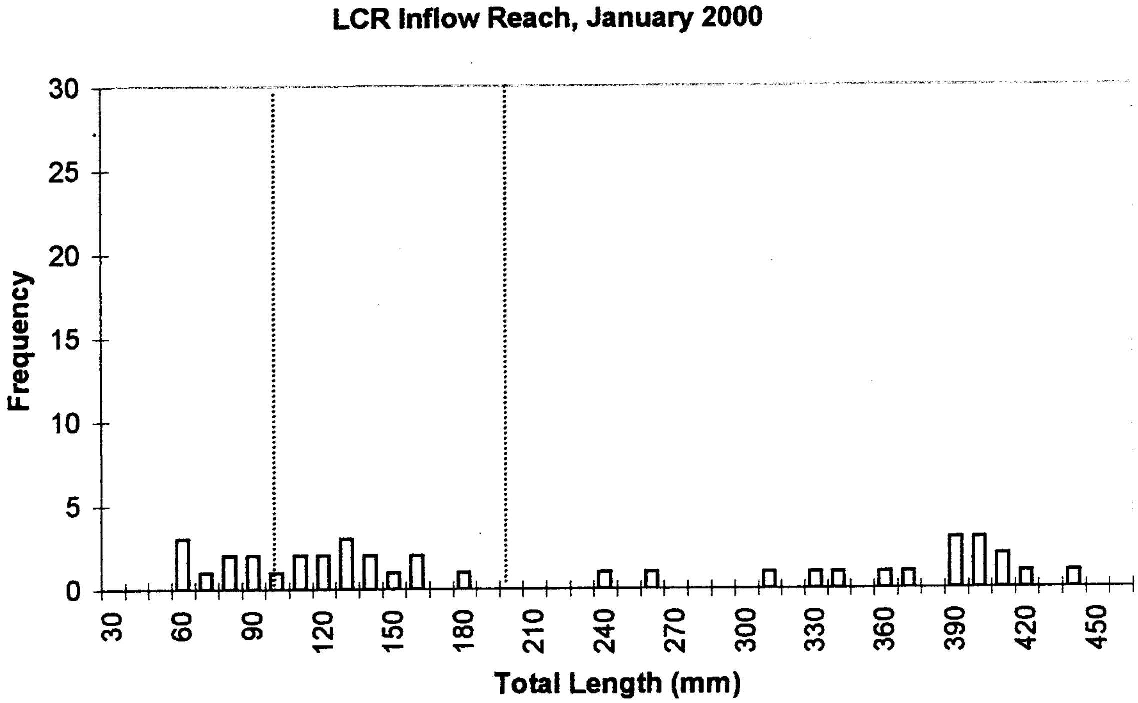
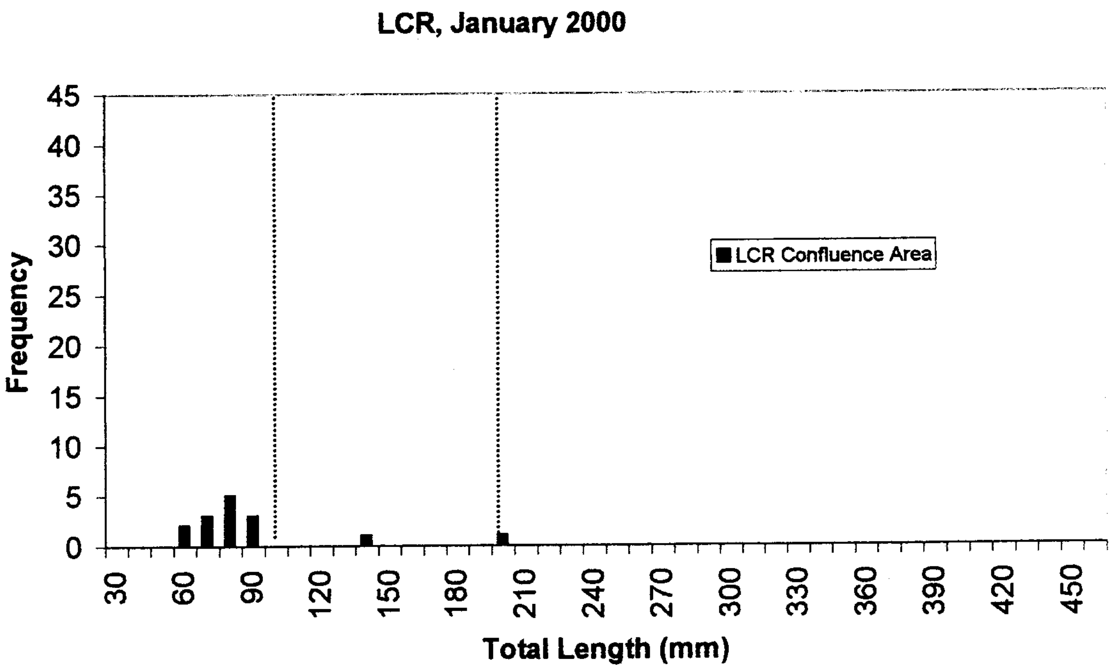


Figure 21. Length-frequency distributions of humpback chub caught in the LCR and LCR Inflow Reach in winter of 2000. Vertical dotted lines at 100 and 200 mm TL are provided for reference.





United States Department of the Interior

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17 July 2000

Dr. Barbara Ralston
Acting Biological Resources Program Manager
Grand Canyon Monitoring and Research Center
2255 N. Gemini Drive, Room 341
Flagstaff, AZ 86001
Tel. 520/556-7455

Dear Dr. Ralston:

Enclosed is a draft final report pursuant to completion of deliverables for Interagency Acquisition No. 98-AA-40-0040, Monitoring and Studies of Native Fishes of the Colorado River Ecosystem in Grand Canyon.

The draft report, "Temporal and spatial distribution and abundance of juvenile humpback chub and adult rainbow trout in the Colorado River in Grand Canyon, 1998-2000" addresses element 2, Evaluation of reproductive success and overwinter survivorship of YOY humpback chub in Grand Canyon as listed in our agreed Outline of Final Report Elements, dated 17 December 1999.

I have sent this draft final report out to scientists within USGS and USFWS for review.

My next report will address element 6, Status and trends in fish communities of Grand Canyon tributary confluences. I expanded the analysis to include mainstem fish communities. It is my intention to have this draft final report completed by 1 September.

Of the the 13 reports listed in the Outline of Final Report Elements, I have now completed 8. I apologize for the delays in completion of these final elements, but limited resources, difficulties in communication with remote staff, and waning support from USFWS, have added to the challenge. Regardless, I am committed to completion of the remaining report elements for this interagency agreement.

Sincerely,

Owen T. Gorman

Owen T. Gorman, Chief
Lake Superior Biological Station